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Universidad del País Vasco
Euskal Herriko Unibertsitatea

Hezkuntza eta Kirol Fakultatea

Gorputz eta Kirol Hezkuntza saila

EGOERA FISIKO, ENTRENAMENDU ETA PARTIDUEN KUANTIFIKAZIOA GURPILDUN AULKIKO SASKIBALOIAN

Aitor Iturricastillo Urteaga

Vitoria-Gasteiz, 2017

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Amamari,

erakutsitako danagaittik

DOKTOREGO PROGRAMA

Jarduera fisikoa eta kirolaren zientziak

DOKTOREGO TESIA

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Gorputz eta kirol hezkuntza saila

“Nuestro conocimiento es necesariamente finito, mientras que nuestra ignorancia es necesariamente infinita” (Karl Popper)

“Jakintsuagotzen gaituen zalantza orokorraren baitan sinisten dudalako” (Xabier Lete)

ESKER ONAK

Zuzendarien nortasunaz, unibertsitate, fakultate eta departamentuaren izaeraz, Zuzenaken konfidantzaz, Landerren eskuzabaltasunaz, Asier Los Arcos-en buruhausteez, Raúl Reina eta Elx-ekoen prestutasunaz, Victoria Goosey-Tolfrey eta Barry Masonen interesaz, bizitzako ikaskide eta lagunen babesaz, bulegokideen ergelkeriez, familiaren maitasunaz eta Itziarren pazientziaz burututako lana. Eskerrak banan-banan ematea, guztiz ezinezkoa zait, hainbeste eta hainbeste bait zarete, hala edo hola, honaino irizten lagundu didazuenak. Beraz, onar ezazue denek, lerro hauetatik esker itzel bat bakoitzak laguncuriko aferarengatik.

DEKLARAZIOA

Tesi honen autoreak lanaren diseinutik hasita publikazioen azken prozesuraino parte hartu du eta nola ez tesi hau idatzi du. Bide honetan, lana diseinatu behar izan du, bibliografiaren azterketa, entrenamendu eta partidutan datuak jaso ditu, datu hauen analisia egin du, emaitzen interpretazio sakona eta eztabaida egokia egiten saiatu da. Bestalde, artikuluak aldizkarietan publikatu ahal izateko egin behar den prozesuaren arduraduna izan da. Hala ere, lan hau ezingo zen tutoreen gidaritza gabe aurrera eraman, lan osoan zehar lagundu dute pausuz pausu, lan hau hasi zenetik amaitu den instanterarte.

Honetaz gain, ikerketa hau Eusko Jaurlaritzako beka predoktoralaren laguntzaz burutu da (erreferentzi zenbakia: PRE_2014_1_21 eta PRE_2015_2_0262) eta Universidad del País Vaso/Euskal Herriko Unibertsitateak (UPV/EHU) eskainitako zerbitzuez.

Bestalde, ikerketa hauek burutzeko orduan ez da inongo interesen gatazkarik izan eta beka predoktoralaren finantzaketak ikerketaren emaitzetan ez du inolako eraginik izan.

IRAKURKETARAKO AHOLKUAK

Esku artean daukazuen tesia artikulu bilduma formatu bidez egin da. Edukien ildoa jarraitzeko, sarrerako kapitulutik hasi beharko du irakurleak. Bertan, kirol egokitua eta gurpildun aulkiko saskibaloiak zientzian duen egoera azaltzen da. Lehenengo kapituluak, ikerketa helburuei pasu emango dio, eta helburuon erantzunak *Journal Citation Reports*-en aurkitzen diren aldizkari internazionaletan argitaratutako lau artikulutan aurkeztuko dira. Lehenengo artikulua "*Changes in body composition and physical performance in wheelchair basketball players during a competitive season"* titulupean, egoera fisiko zein gorputz konposizioak urtean zehar eduki ditzakeen aldaketez mintzo da. Aldaketa hauek entrenamendu zein partiduen efektuaren ondorioz gertatzen dira. Hau dela eta, hurrengo artikuluetan entrenamendu tareak eta partiduek zein nolako barne karga duen aztertuko da. Horretarako, entrenamendu tareen influentzia aztertzeko helburuarekin, bigarren artikuluaren titulua "*Objective and subjective methods for quantifying training load in wheelchair basketball small-sided games"* da. Bertan, 4 vs. 4 joko murriztuen egoeran, jokalarien barne karga dago aztergai. Are gehiago, barne karga objektibo eta subjektiboen arteko koerlazioak aztertzen dira. Bide beretik jarraitzen du hirugarren artikuluak, "*Physiological responses between players with and without spinal cord injury in wheelchair basketball small-sided games".* Kasu honetan ordea, bizkar muineko lesioa duten eta bizkar muineko lesioa ez dutenen artean erantzun fisiologikoak konparatzen dira joko murriztuetan. Gurpildun aulkiko saskibaloiko partiduetan jokalariek zer nolako barne karga duten aztertzeko, laugarren artikulua aurkezten da, "*Quantifying wheelchair basketball match load: a comparison of heart rate and perceived exertion methods"*. Partiduek daukaten barne karga aztertzeko helburua duen artikulu honetan metodo objektibo eta subjektiboen arteko koerlazioak ere aztertzen dira. Tesi honen azken zatian ondorio orokorrak eta etorkizuneko ikerketa lerroak aurkezten dira hurrenez hurren.

Azkenik, hizkuntzari buruzko aipamen bat: tesia funtsean, euskaraz aurkezten da baina barneratutako artikuluak nazioartekoak izanik, kapitulu batzuk ingelesez idatziak daude. Beraz, tesian zehar bi hizkuntza agertuko dira: euskara eta ingelesa. Testuan aurkituko dituzuen artikuluen formatua bateratua izan da, hala ere, artikuluak formatu originalean eskuragarri daude eranskinetan. Irakurketa errazteko asmoarekin, laburduren esanahiak beti eskura izango dira orrialde markatzailean.

LABURDURAK

BM = bihotz maiztasuna

BML = bizkar muineko lesioa

CL = konfidantza limitea

d = tamainaren efektua

GAS = gurpildun aulkiko saskibaloia

HR = bihotz maiztasuna

IWBF = nazioarteko gurpildun aulkiko saskibaloi federazioa

ML = partiduko karga

Non-SCI = bizkar muineko lesioa ez dutenak

p = adierazgarritasun estatistikoa

r = Pearsonen koerlazioa

R^2 = determinazio koefizientea

RPE = hautemandako nekea

RPEres = hautemandako arnasketa nekea

RPEmus = hautemandako neke muskularra

SCI = bizkar muineko lesioa

sRPE = saioan hautemandako nekea

sRPEres = saioan hautemandako arnasketako nekea

sRPEmus = saioan hautemandako neke muskularra

sRPEres ML = partiduan hautemandako arnasketako nekea

sRPEmus ML = partiduan hautemandako neke muskularra

SSG = joko murriztuak

TL = entrenamendu karga

TRIMPmod = Stagnok eraldatutako entrenamendu karga

V = erregresioaren aldakuntza

WB = gurpildun aulkiko saskibaloia

YYIR1 = Yo-Yo aldizkako errekuperazio erresistentzi testa

LIST OF ABBREVIATIONS

BM = heart rate

BML = spinal cord injury

CL = confident limit

d = effect size

GAS = wheelchair basketball

HR = heart rate

IWBF = international wheelchair basketball federation

ML = match load

Non-SCI = non spinal cord injury

p = statistical significance

r = Pearsons correlation

R^2 = coefficient of determination

RPE = rating of perceived exertion

RPEres = respiratory rating of perceived exertion

RPEmus = muscular rating of perceived exertion

SCI = spinal cord injury

sRPE = session rating of perceived exertion

sRPEres = respiratory session rating of perceived exertion

sRPEmus = muscular session rating of perceived exertion

sRPEres ML = respiratory session rating of perceived exertion during match load

sRPEmus ML = muscular session rating of perceived exertion match load

SSG = small-sided games

TL = training load

TRIMPmod = Stagno's modified training impulse

V = variation about regression

WB = wheelchair basketball

YYIR1 = Yo-yo intermittent recovery endurance test

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1. LEHENENGO KAPITULUA

SARRERA

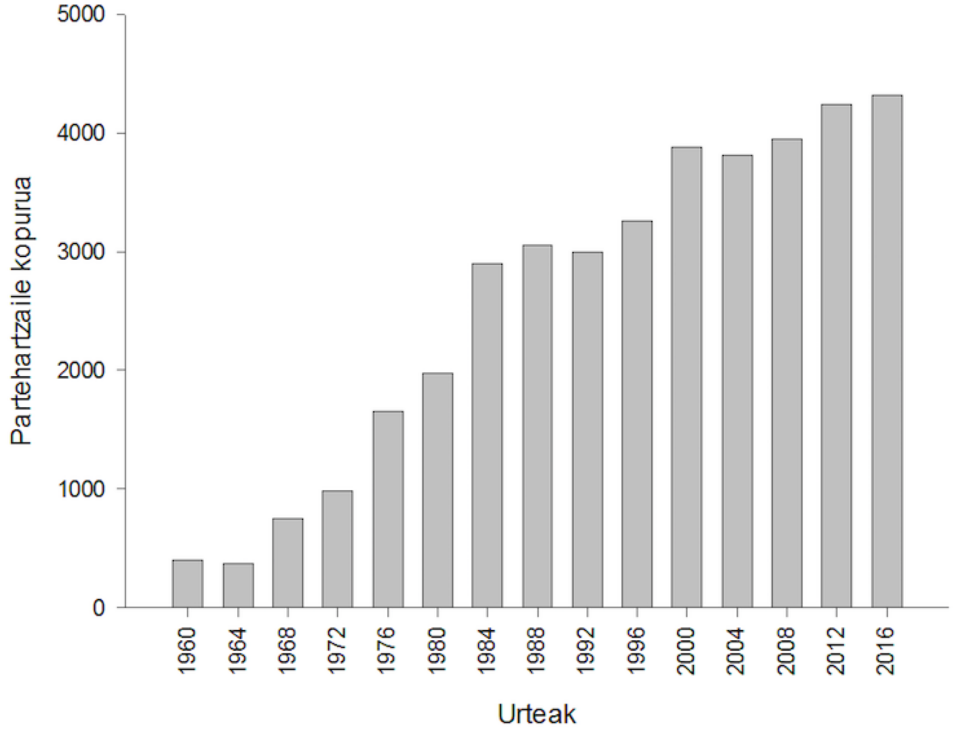
SARRERA

Gurpildun aulkiko saskibaloiaren (GAS) historiaren hasiera Estatu Batuetan, 1945. urtean kokatzen da, Bigarren Mundu Gerra osteko testuinguruan. GAS jokalari antzindariok, sendaketa prozesuan murgilduta zeuden soldadu beteranoak izan ziren (IWBF, 2016). Beste herrialde batzuetan, Britania Handian kasu, gurpildun aulkiko kirolen lehenengo zantzuak 1948. urtean aurkitzen dira. Gurpildun aulkiko *netball*-ean jokatzen hasi ziren Stoke Mandevill-eko ospitalean zeuden gerrako beteranoak, *Sir* Ludwig Guttmann doktorearen preskripzioz eta bere ikuskaritzapean (Griggs et al., *in press*). Urte gutxiren buru, GAS-ko lehenengo txapelketa nazioala ospatu zen 1949. urtean, Estatu Batuetako Illinois hirian. Guztira, sei taldek parte hartu zuten. Urte horretan bertan, *National Wheelchair Basketball Association* sortu zen herrialde berean (IWBF, 2016).

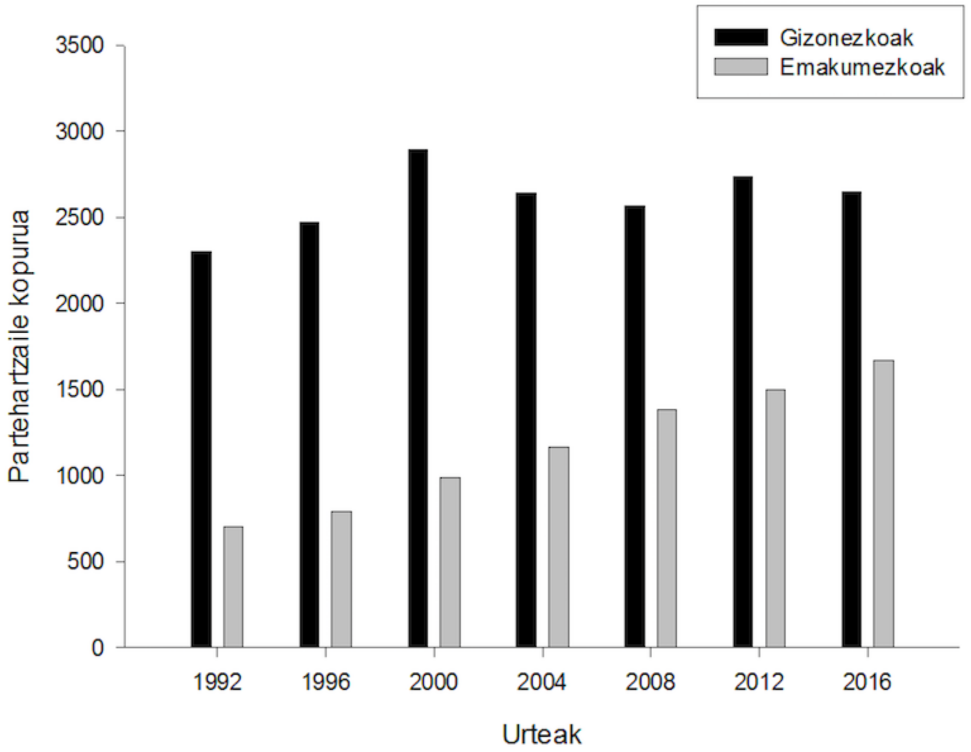
GAS 1955. urtean iritsi zen Europara, *Stoke Mandevillera* hain zuzen ere eta bost urte geroago, 1960. urtean GAS Erromako lehenengo joko paralinkikoetako kiroletako bat izan zen. 1960az gero, joko paralinpikoetako partehartzea hamar aldiz igo da (400 vs. 4316 atleta) (1.go irudia) (Vanlandewijck & Thompson, 2011) eta honekin bat emakumezkoen partehartzea (2. irudia). Azpimarratzekoa da Rio de Janeiro 2016-ko joko paralinpikoetan 176 herrialdek hartu dutela parte 1960ko paralinpiar jokoaetan baino bost aldiz gehiago (23 vs. 176 herrialde) (Lepêtre et al., 2016).

Gurpildun aulkiko beste kiroletan bezala, jokalari baten urritasun motak (Paulon & Goosey-Tolfrey, *in press*) eta antropometriak (Goosey-Tolfrey et al., 2016; Sutton et al., 2009) eragin handia izango du jokalariaren ezaugarri fisikoetan eta ondorioz ezaugarri fisiko hauek garatu eta entrenatzerakoan (3. Irudia). Hori dela eta, gurpildun aulkia behar duten kirolentzako sailkapen sistema bat diseinatu zen; alde batetik, aniztasun funtzionalak txapelketako emaitzetan izan dezakeen inpaktua txikiagotu eta bestetik, lehian zehar berdintasuna bultzatzeko (Tweedy & Vanlandewijck, 2011; Tweedy & Diaper, 2010).

GAS-ko sailkapena jokalarien ahalmen funtzional eta jokatzeko beharrezkoak diren abilezietan oinarritzen da; aulkiaren propultsioa, pibotatzea, jaurtiketa, errebotea, dribbling-a, pasea eta harrera, hurrenez hurren (International Wheelchair Basketball Federation, 2014). Sailkapen sistema honek ordea, ez du jokalariaren abilezien maila baloratzen, ariketa burutzeko jokalariaren ahalmen funtzionala baizik (International Wheelchair Basketball Federation, 2014). Oro har, jokoan zehar gorputz enborarren mugimendua eta estabilitatea baloratzen da eta jokalari bakoitzari puntuazio zehatz bat ezartzen zaio. Aitortutako jokalarien puntuazioa 1, 2, 3, 4-koa izan daiteke, baina kasu berezietan, hau da, jokalari batek klase horietako ezaugarri funtzionalak guztiz betetzen ez dituenean, 0.5 puntuazioa erabiltzen da. Urritasun funtzional txikiena duten pertsonen kasuan, 4.5 puntuazioa erabiltzen da (International Wheelchair Basketball Federation, 2014). Puntuazioa experientzidun eta formatutako pertsonek egin zuten



1.go irudia: Joko paralinpikoetan izandako kirol guztietako partehartzaile kopurua (Vanlandewijck & Thompson, 2011-tik egokitua).



2. Irudia: Gizonak eta emakumezkoen partehartzeale kopurua joko paralinpikoetako kirol guztietan.

sailkapen sistemaren gida zintzotasunez jarraituz (International Wheelchair Basketball Federation, 2010.).

Espainiako GAS garapenak esponentzialki gora egin du. 2013-2014 denboraldian GAS-ko 2 maila zeuden (Federación Española de Deportes de Personas con Discapacidad Física, 2016); 12 talde lehenengo mailan bi multzotan bananduta eta 24 talde bigarren mailan lau multzotan bananduta: iparraldea, hegoaldea, ekialdea eta zentroa. Lehenengo mailan 138 jokalari zeuden eta bigarren mailan berriz, 304. Espainian 2013-2014 denboraldian liga guztiak batuta 415 jokalarik jokatzen zuten GAS-ra (1.go taula).

1.go taula. 2013-2014 denboraldian GAS-n Espainiako ligetan jokatzen zuten jokalari kopurua.

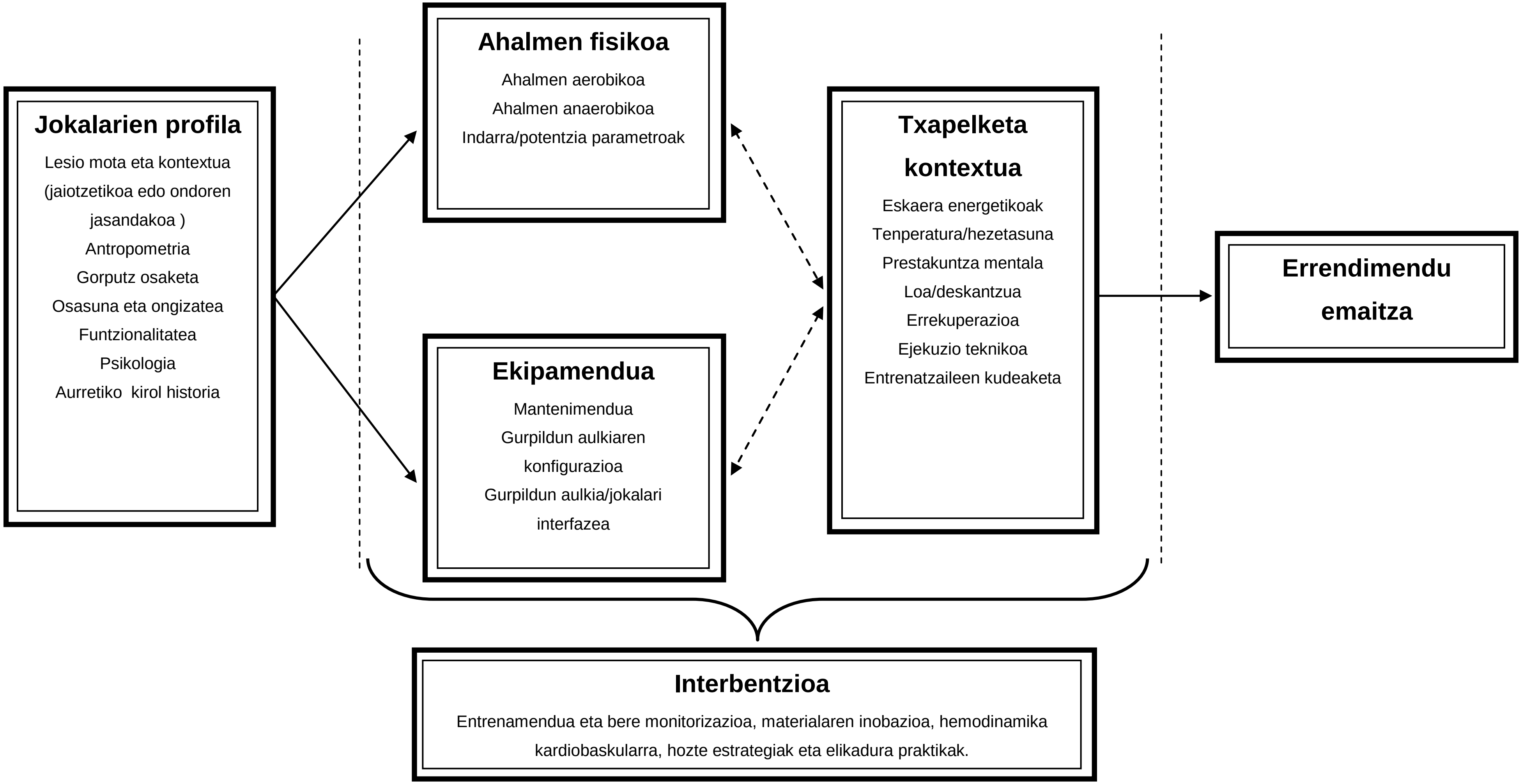
	Gizonezkoak	**Emakumezkoak**	**IWBF 1.0-1.5**	**IWBF 2.0-2.5**	**IWBF 3.0-3.5**	**IWBF 4.0-4.5**
1.go maila	131 (%93.6)	9 (%6.4)	31 (%22.2)	40 (%28.5)	22 (%15.7)	47 (%33.6)
2. maila	284 (%93.4)	20 (%6.6)	75 (%24.7)	86 (%28.3)	54 (%17.8)	89 (%29.3)
Guztira	415 (%92.1)	29 (%7.9)	106 (%23.9)	126 (%28.4)	76 (%17.1)	136 (%30.6)

GAS = Gurpildun aulkiko saskibaloia; IWBF = International Wheelchair Basketball Federation. Emaitzak pertsona kopurua dira eta parentesietan jokalari kopuru totalaren portzentaiak azaltzen dira.

GAS-an kirol errendimenduak, jokalari eta aulkiaren arteko integrazioa beharrezkoa du, bi elementuak unitate bakarra sortuz (gurpildun aulkiko jokalari interfazea) (Paulon & Goosey-Tolfrey, *in press*). Hala ere, urritasun fisikoen heterogeneitateak eta sailkapenak aparteko erronka bat aurkezten die entrenatzaile eta kirol profesionaleei, errendimendu fisikoaren alorrean. Ikertzaile eta kirol profesionalen erronka, sailkapen sistemak aurkezten dituen ezberdintasunak identifikatu eta konfidantzazko protokoloak inplementatzean datza, honela, gurpildun aulkiko jokalari interfazeak ahalmen fisikoak hobetuz eta ondorioz txapelketa errendimendua handituz (3. Irudia). Kontuan izan behar da kirol egokituan, errendimendua bermatzen duen ebidentziaren oinarria bere hasieran dagoela oraindik urritasunik gabeko kirolekin alderatuz gero (Paulson & Goosey-Tolfrey, *in press*).

Kirol paralinpikoan profesionalismoa gehitzen doa, batez ere GAS-n, eta harrigarria dirudien arren, hutsarte handiak aurkitzen dira ikerketetan eta oraindik gauza gutxi dakigu jokalariek txapelketa egoeran dituzten kanpo eta barne kargaren inguruan (Paulson & Goosey-Tolfrey, *in press*). GAS aldizkako kirola da, bertan maiz gertatzen diren intentsitate altuko azelerazio eta dezelerazioak gertatzen dira, egoera aerobiko eta anaerobikoak konbinatuz (Weissland et al., 2015a). Ondorioz, GAS-ko jokalarien karga zehaztasunez kuantifikatzeko, entrenamendu zein partiduen testuinguruan, kanpo eta barne kargaren monitorizazioak berebiziko garrantzia dauka. Gaur egun, GAS-en eta partiduen testuinguruan, kanpo karga aztertu duten bi ikerketa aurkitu dira (Bloxham et al., 2001; Van der Slikke et al., 2016) eta badira barne karga aztertu duten beste bost ikerketa (Coutts, 1988; Croft et al., 2010; Iturricastillo et al., 2016a; Iturricastillo et al., 2016b; Schmid et al., 1998). Ikerketa hauetatik azelerazio eta dezelerazioak Van der Slikke et al. (2016) autoreek aztertu dituzte eta egoera aerobiko eta anaerobikoak Croft et al. (2010)-ek. Ikerketa guzti hauek batuz gero (Bloxham et al., 2001; Coutts, 1988; Croft et al., 2010; Iturricastillo et al., 2016a; Iturricastillo et al., 2016b; Schmid et al., 2013; Van der Slikke et al., 2016) GAS-ko kanpo eta barne kargaren ideia orokor bat egitea ahalbidetzen den arren, GAS ezaugarriak zehazteko ikerketa kuantitatibo gehiagoren beharra dagoela azpimarratu behar da.

GAS-ko kanpo karga partidutan ikertu dutenak, bereziki, Van der Slikke et al. (2015) izan dira, hala ere, badira beste autore batzuk mugikortasun errendimendua aztertu dutenak partidutan zehar (De Witte et al., 2016). Kanpo kargaren inguruan dauden azterketetan, gurpildun aulkiko errugbiko lan batzuk nabarmendu behar dira (Paulson et al., 2015; Rhodes et al., 2015a; Rhodes et al., 2015b; Rhodes et al., *in press*). Gurpildun aulkiko errugbiko ikerketek partidu eta entrenamenduetan jokalariek egindako metroak eta abiadura intentsitateak aztertu zituzten erradiofrekuentziako sistema baten bidez. Taldeko kiroletan abiaduren intentsitatea jakitea garrantzitsua izan arren, are garrantzitsuago suertatzen da azelerazio eta dezelerazioen azterketa. Aldagai hauek, asko ikertu izan dira *outdoor* egiten diren talde kiroletan global positioning system-en (GPS) bidez (Castagna et al., *in press*; Castellano & Casamichana, 2013; Meylan et al., *in press;* Owen et al., 2015), ez ordea, *indoor* egiten diren kiroletan, zailtasunak baitaude GPS materiala erabiltzeko. Honetarako, Van der Slikke et al. (2015) -ek *Inertial Measurement Unit* erabili zuten GAS-ko jokalari bakoitzaren jokoko errendimendua aztertzeko. Sailkapen funtzionalaren arabera puntuazio baxua zuten jokalariek (1.0 – 1.5 puntuazioa) talde osoaren media baino balore baxuagoak lortu zituzten abiadura, errotazio eta azelerazio aldagaietan. Puntuazio altuena zutenek berriz (4.0-4.5 puntuazioa), abiadura, errotazio eta azelerazio emaitza hoberenak lortu zituzten. Tarteko jokalariak (2.0-3.0 puntuazioa), aurrerantzko abiadura klase baxuko (1.0-1.5 puntuazio) jokalarien antzekoa zuten, baina klase altukoen (4.0-4.5 puntuazio) errotazio abiadura. Ikerketa honetan, argi ikusten da urritasun fisikoak jokalariaren ezaugarri fisikoetan izan dezakeen eragina aurretik aipatu bezala. Ikerketa honek partiduen kanpo karga nolakoa den erakusten du, entrenamendu fisikoaren ikuspuntutik zer entrenatu behar denaren ideia bat emanez.



3. Irudia: Gurpildun aulkiko saskibaloiko (GAS) errendimendua baldintzatzen duten aldagaiak (Paulson & Goosey-Tolfrey, 2016-tik egokitua).

GAS-ko jokoaren barne karga jakitea kanpo kargaren ezagutzaren bestekoa da entrenamendu programa eraginkorrenak aukeratu, lesioak saihestu eta ahalmen fisiko hobeak ahalbidetzeko (Paulson & Goosey-Tolfrey, *in press*). Barne karga metodo objektibo edo subjektiboen bidez neurtu izan da urritasun gabeko talde kiroletan, partidu (Moreira et al., 2012; Sparks et al., *in press*; Torreño et al., 2016) eta entrenamenduen (Campos-Vazquez et al., 2015; Impellizzeri et al., 2004) eraginkortasuna aztertzeko asmoz. Urritasunik gabeko saskibaloian helburu honi erantzuten dioten hainbat ikerketa aurkitzen diren arren (Ben Abdelkrim et al., 2007; Delextrat & Kraiem, 2013; Manzi et al., 2010; Scanlan et al., 2014), kirol egokituan metodo hauen erabilera urria da (Paulson et al., 2015; Roy et al., 2006; Sanchez-Pay et al., 2016; Sindall et al., 2013; Menaspà et al., 2012), eta ondorioz GAS-n (Croft et al., 2010; Pretorious et al., 2015; Iturricastillo et al., 2016a; Iturricastillo et al., 2016b). GAS-en metodo objektiboak neurtzeko bihotz maiztasuna erabili izan da metodo subjektiboak neurtzeko berriz, pertzepzio eskalak (Lewis et al., 2007; Goosey et al., 2010b; Graham-Paulson et al., 2016). Bihotz maiztasunaren neurketa pultsometroak erabiliz burutzen da baina kontuan izan behar da, Espainian GAS-eko talde askok ez dituztela pultsometroak eskuragarri izaten. Hau dela eta, beharbada metodo merkeago eta eskuragarriagoen beharra dago, batez ere, bihotz maiztasuna erregistratzeko pultsometroak ez dituzten taldeentzako.

Pertzepziozko eskaletan bereizketa egiten da arnasketa pertzepzioa eta pertzepzio muskularrean GAS-k ezaugarri bereizle bat baitu (Paulson et al., 2015); goiko gorputzadarrek lan bolumen handia egiten dute gurpildun aulkia bultzatzean eta honek jokalariek neke periferikoa izateko joera ekartzen du (Lenton et al., 2008). Gainera, sorbaldako masa muskulurra erlatiboki txikia da baina mugikortasun askokoa, eskapulako zonak estabilitate txikia izanda. Hori dela eta, gurpildun aulkiko propultsioa mekanikoki ariketa inefizientea da (Paulson & Goosey-Tolfrey, 2016). Jokalarien hetereogeneitate handiak eta beraien egoera fisikoak metodo subjektiboekin neurtutako barne kargaren emaitzetan eragin handia izan dezakete (Paulson et al., 2013). Autore batzuren arabera, hautemandako nekearen metodoa (RPE) bihotz maiztasunaren neurketa baino metodo hobea dela adierazten dute (Paulson et al., 2013), bihotz maiztasunaren media ez dagoelako kanpo kargarekin zuzenki erlazionatuta. Hala ere, ikerketa honetako partehartzaileak tetraplegikoak ziren, eta GAS-ko partehartzaileen ezaugarrietatik aldentzen den perfil bat da. Bizkar muineko lesio (BML) altua duten pertsonek bihotz maiztasunaren (BM) erantzun urritasuna dute eta oxigeno kontsumoak RPE-rekin erlazio ona adierazi dute (Paulson et al., 2015). GAS-ko kasuko ikerketa baten, BML altua duen jokalari baten BM erantzunak neurtu ziren GAS-ko partidu baten eta normala den bezala, balore absolutotan ezberdintasunak zeuden, ez ordea balore erlatibotan (Iturricastillo et al., 2016c). Kasu honetan, partehartzaile horretan BM monitorizazioa bermatzen zuen, nahiz eta bihotzeko inerbazio autonomoan urritasuna eduki, honela, BM maximo txikiago bat edukiz. Price-n (2010) arabera, nerbio sistema sinpatikoaren inerbazio eta bihotzaren funtzioaren urritasunaren erruagatik, ariketa maximoa egiteko ahalmena murriztuta dago urritasunik gabeko jokalariekin alderatuz gero.

GAS-ko jokalarien errendimendu fisikoa ikertzaile askok neurtu dute test desberdinen bitartez (Molik et al., 2010; Molik et al., 2013; Vanlandewijck et al., 1999; Vanlandewijck et al., 2004; Weissland et al., 2015a; Weissland et al., 2015b) baina denboraldi batean zehar errendimendu fisikoaren garapenaren baitan bi ikerketa besterik ez dira aurkitu (Ayán et al., 2014; Iturricastillo et al., 2015). Guztiz kontrakoa pasatzen da urritasunik gabeko talde kiroletan, non, asko diren errendimendu fisikoaren garapena aztertzen dituzten ikerketak (Cadwell & Peters, 2009; Casajús, 2001; Mikuluc, 2012). Are gehiago, denboraldi osoa aztertu beharrean denboraldi une bat edo ariketa konkretu bat aztertzen duten ikerketa ugari ere badira (Aoki et al., 2017; Fessi et al., 2016; Gonzalo-Skok et al., 2016). Talde kiroletan, barne logikarekin lotutako ariketak aztertzen dituzte, horietako askok, joko murriztuen antzeko ariketa ezberdinak aztertzen dituzte, jokoaren barne karga kuantifikatzeko helburuz (Castellano et al., 2013; Delextrat & Kraiem, 2013; Dellal et al., 2011; Fanchini et al., 2015; Klusemann et al., 2012; Sampaio et al., 2009). Hauetaz aparte, zirkuitoak (Campos-Vazquez et al., 2015) edota indar ariketen erantzunak eta eragina aztertzen dituzten ikerketak ere aurkitzen dira (Freitas et al., 2016). Kirol egokituan eta GAS-n zehazki, badira denboraldi une jakin baten egoera fisikoaren bilakaera aztertu dutenak (Turbanski et al., 2010; Bergamini et al., 2015; Skucas & Pokvytyte, *in press*; Granados et al., 2016). GAS-ko jokalariek indarra eta potentzia hobetu zuten 8 asteko *press* banka-ko indar interbentzio baten ondoren (Turbanski et al., 2010). Hobekuntza hauek errendimendu fisikoarekin erlazionatu ziren, 10 metroko sprintarekin hain zuzen ere. Jokalariak %6.2 azkarragoak izan ziren 8 asteko interbentzioaren ondoren. Skucas & Pokvytyte (*in press*) arabera, 2 asteko interbentzio aerobiko baten ondoren jokalarien erresistentzia aerobikoa hobetzen dute. Interbentzio hau ordea, ez da saskibaloiko kantxan egiten, laborategian baizik. Granados et al., (2016), denboraldi erdian 10 asteko interbentzio programa bat egin zuten intentsitate altuko zirkuitoak erabiliz. Kasu honetan, ez zen inongo hobekuntzarik ikusi, are gehiago, hain oinarrizkoa den 5m-ko sprintean %7-ko galera egon zen. Hau dela eta ikerketa gehiagoren beharra ezinbestekoa da GAS-n urte osoko jokalarien egoera fisikoaren garapen edo bilakaera ulertzeko.

Badira urte batzuk, talde kiroletan joko murriztuak erabiltzen direla jokalarien errendimendu fisikoa hobetzeko helburuarekin jokoaren barne logikatik asko urrundu gabe (Castellano et al., 2013; Delextrat & Kraiem, 2013; Dellal et al., 2011; Fanchini et al., 2015; Klusemann et al., 2012; Sampaio et al., 2009). Joko murriztuak jokalarien erabaki hartzea hobetu dezaketen entrenamendu tarea espezifikoak dira eta era berean jokoaren barne logika mantentzen dute (Hoffmann et al., 2014). Hau honela izanik, abilezi ezberdinetan eta jokoaren mugimendu espezifikoetan oinarriturik, errendimendu fisikoa hobetu edo mantentzeko estimulo egoki bat denez, talde kiroletan geroz eta gehiago erabiltzen hasi dira (Halouani et al., 2014). Joko murriztuen alorrean GAS-n oso ikerketa gutxi egin dira (Yanci et al., 2014; Iturricastillo et al., 2016d; Iturricastillo et al., 2017), beraz, ezer gutxi dakigu, joko murriztuetan GAS-ko jokalariek dituzten erantzun fisiologiko eta barne kargaren inguruan eta zer esanik ez kanpo kargaren inguruan. Honetaz gain, ez dakigu BML dutenentzako karga BML ez dutenentzako berdina den ala ez. Ikerketa asko behar dira entrenamendu mota honen inguruan eta nola ez joko murriztuek duten efektuaren inguruan, beti ere, entrenamendu sistemak hobetzen joateko helburuarekin.

2. BIGARREN KAPITULUA

HELBURUAK ETA HIPOTESIAK

HELBURUAK ETA HIPOTESIAK

1. Gorputz konposizioa eta errendimendu fisikoaren garapenaren azterketa egitea gurpildun aulkiko saskibaloiko jokalarien txapelketa denboraldian.
    - Gorputz konposizioan aldaketa nabariak izan daitezkela hipotetizatzen da, entrenamendu eta partiduen eraginagatik.
    - Errendimendu fisikoan aldaketa txikiak baina batzutan erabakigarriak izango direla hipotetizatzen da.

2. Metodo objektibo eta subjektiboen bidez joko murriztuen barne karga neurtzea eta serieen arteko eboluzioa aztertzea. Honetaz gain, metodo objektibo eta subjektiboen arteko erlazioa ikertzea.
    - Joko murriztuen barne karga handia izango dela hipotetisatzen da, eta serien arteko ezberdintasunak nabarmenak izango direla.
    - Metodo objektiko eta subjektiboen arteko erlazioa ez da altua izatea espero, talde kirol intermitentea delako eta urritasunen heterogeneitateagatik.

3. Joko murriztuetan, erantzun fisiologikoetan bizkar muineko lesioa dutenen eta ez dutenen arteko ezberdintasunak dauden aztertzea. Erantzun fisiologikoen bilakaera neurtzea eta bizkar muineko lesioa dutenen eta ez dutenen arteko ezberdintasunak aztertzea.
    - Erantzun fisiologikoen balore absolutoetarako ezberdintasun nabariak izango direla hipotetisatzen da bizkar muineko lesioa dutenen eta ez dutenen artean.
    - Erantzun fisiologikoen balore erlatiboentzako ez dira ezberdintasun nabariak espero bizkar muineko lesioa dutenen eta ez dutenen artean.

4. Partiduetako barne karga metodo objetktibo eta sujektiboen bidez neurtzea eta bi metodoen arteko koerlazioak aztertzea denboraldi osoko partiduetan.
    - Metodo objektibo eta subjektiboen bidez neurtuko barne karga altua izango dela hipotetisatzen da gurpildun aulkiko saskibaloiko partiduetan.
    - Metodo objektibo eta subjektiboen arteko erlazioa altua ez izatea espero da, talde kirol intermitentea delako eta urritasunen heterogeneitateagatik.

3. HIRUGARREN KAPITULUA

Changes in body composition and physical performance in wheelchair basketball players during a competitive season

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3.1. Abstract

Purpose: the present study analyzed the changes in body composition and physical performance in wheelchair basketball (WB) players during one competitive season. **Methods:** Players from a WB team competing in the first division of the Spanish League (n = 8, age: 26.5 ± 2.9 years, body mass: 79.8 ± 12.6 kg, sitting height: 91.4 ± 4.4 cm) participated in this research. **Results:** The upper limbs showed a decrease in subcutaneous adipose tissue and there was an improvement in physical abilities such as sprinting with the ball (5 and 20 m), handgrip and aerobic capacity. However, the changes in physical fitness concerning sprinting without the ball and agility tests were low. **Conclusions:** It would be interesting to study the effects of implementing specific programs to improve physical performance in WB and to establish more test sessions to monitor the effects of the programs followed.

Keywords: *adapted sports, anthropometrics, skinfolds, physical performance, field tests*

3.2. Introduction

Wheelchair basketball (WB) is one of the most popular sports among the Paralympic disciplines and is practiced by people with different disabilities, according to the classification protocol of the International Wheelchair Basketball Federation (IWBF). WB is an intermittent sport which combines repeated high intensity sprints and rapid accelerations and decelerations with moderate and low intensity actions, with the purpose, among other aims, of achieving or maintaining a good position on the court (Molik et al., 2010). In this sense, both anaerobic and aerobic capacities are important for a better performance, during offensive and defensive situations (Molik et al., 2013). Body composition is also a significant factor affecting performance in WB.

Several studies have determined the importance of anthropometry in sport, and it is perhaps even greater in adapted sports, where certain players with spinal cord injury may experience a loss of metabolic activity in active fibers and muscle mass due to their particular injury (Collins et al., 2010). For this reason some authors have studied body composition using skin folds in wheelchair basketball and tennis players (Sutton et al., 2009). In this regard, some researchers have stated that both the player's functional potential (Vanlandewijck et al., 2004) and their body composition (Goosey-Tolfrey et al., 2003) will influence physical performance in WB. Therefore, it could be important for coaches to study the evolution of the anthropometric characteristics of WB players during a competitive season.

Several articles describe the physical qualities of WB players under laboratory conditions (Goosey-Tolfrey et al., 2003; Goosey-Tolfrey et al., 2008; Molik et al., 2010) and also using field tests carried out in their own playing area (De Groot et al., 2012; Vanlandewijck et al., 1999). Among the field tests, the most important are those that measure sprint capacity, change of direction ability and muscle strength (Goosey-Tolfrey et al., 2008; Molik et al., 2013; Yanci et al., 2015), and obviously those that measure aerobic capacity (Goosey-Tolfrey and Tolfrey, 2010a; Vanlandewick et al., 1999). However, we have only found one study which monitored the changes in physical fitness of WB players (Ayán et al., 2014). Given the absence of research to corroborate these findings, more studies on this topic are needed to analyze the changes in physical performance during a competitive season.

Therefore, the purpose of the present study was to analyze the changes in body composition and physical performance in elite WB players during one competitive season.

3.3. Material and Methods

Participants

Players from a WB team competing in the first division of the Spanish League (n = 8, age: 26.5 ± 2.9 years, body mass: 79.8 ± 12.6 kg, sitting height: 91.4 ± 4.4 cm) participated in this research. All the subjects were informed about the risks and benefits of taking part in the study, knew that they could withdraw at any time, and signed a mandatory informed consent form.

Procedures

The tests were carried out on the basketball court where the team trained. A week before the start of the official competitive season (Pre test), different tests were performed to assess body composition and physical performance. At the end of the season, a week after the last league match (Post test) the same tests were repeated. On the first day the players performed the acceleration tests (5 and 20 m sprint with and without the ball) and the agility tests (T-test and Pick-Up test). On the second day (48 hours later) the measurements of body composition were taken, and the strength tests (maximal pass, medicine ball throw and handgrip) and the intermittent Yo-Yo Level 1 test of 10 m (YYIR1 10 m) were conducted. Before performing the test battery the players carried out a standard warm-up consisting of 5 min of low intensity wheelchair propulsion, two straight line accelerations of 10 m and two accelerations of 10 m with changes of direction. All the participants performed the tests in their usual wheelchair.

Test battery

Body composition. The anthropometric variables of body mass (kg) and skin folds (mm) were measured in each player. Body mass was obtained to the nearest of 0.1 kg using an electronic scale (Seca® Instruments Ltd., Hamburg, Germany) and four skin folds were measured (triceps, subscapular, suprailiac, and abdominal) with a skin fold caliper (Harpender Lange®, Cambridge, MA, USA) bearing in mind the indications specified by Goosey-Tolfrey et al. (2003). The same person recorded all the anthropometric variables on all occasions.

5 and 20 m sprints (with and without the ball). Three accelerations were performed over 5 and 20 m in a straight line with and without the ball (De Groot et al., 2012), with a 2 min rest period between each sprint, which was enough time to return to the start and wait for their next turn. The participants were placed at 0.5 m from the starting point and began when they felt ready. The timer was activated automatically as the subjects passed the first gate at the 0.0-m mark and split times were then recorded at 5 and 20 m (Granados et al., 2015). The time taken was recorded using three photocells (Microgate® Polifemo, Bolzano, Italy). The best time was used for further analysis.

T-test. The participants had to complete a circuit in the shape of a T according to the specifications of Yanci et al. (2015) for WB players. They began with the wheels 0.5 m from cone A, and completed the circuit as follows (Figure 1A), with modifications to allow performance in a wheelchair and always using forward movements (Yanci et al., 2015). Three repetitions were performed with 3 min rest between them. The time was recorded with a photocell (Microgate® Polifemo, Bolzano, Italy). The best result was used for further analysis.

Pick-up. The test was performed three times with 3 min rest between, following the indications of De Groot et al. (2012). From a stationary position, the participant had to start propelling their chair and pick up 4 basketball balls from the floor twice with the left hand and twice with the right hand (Figure 1B). Three repetitions were performed with 3 min rest periods between them. Time was recorded using two photocells (Microgate® Polifemo, Bolzano, Italy) placed at the beginning and the end of the course. The best time was used for further analysis.

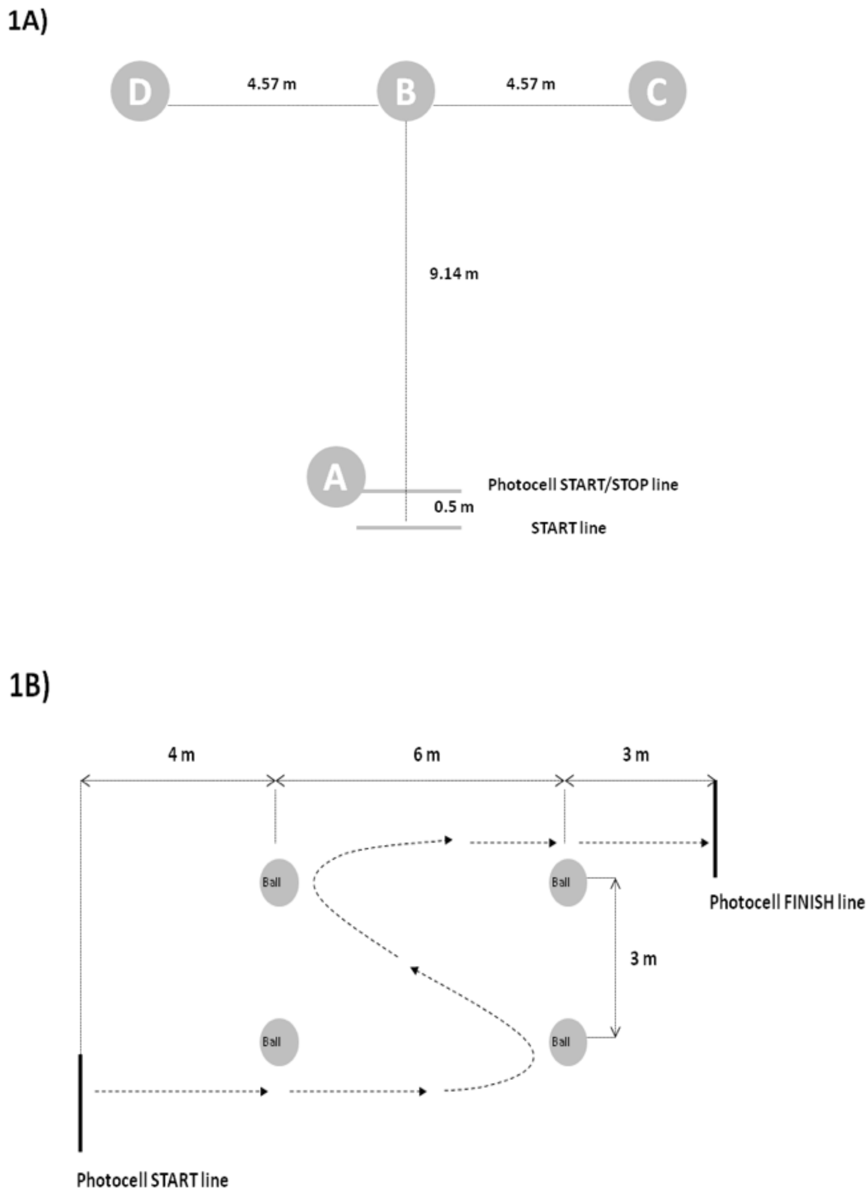

Figure 1. *Agility T-test (1A) and Pick up test (1B)*

Maximal pass. The subjects lined up at the marked line, with their front wheels behind the line, and performed three bilateral throws with a basketball trying to throw it as far as possible (De Groot et al., 2012). The distance was measured (m) between the marked line and the place where the ball bounced for the first time. The final score used for the statistical analysis was the average distance of five throws (De Groot et al., 2012).

Medicine ball throw. From the same position used in the *maximal pass* test, the players had to throw the 5 kg medicine ball as far as possible (Gonaus and Muller, 2012; Yanci et al., 2015). Each player was allowed three attempts and the distance was measured in m from the throwing line to the place where the ball made its first contact with the ground. The best of the three results was used for statistical analysis.

Handgrip. Forearm strength was measured in the dominant hand (Molik et al., 2013) using a portable hydraulic hand dynamometer (5030J1, Jamar®, Sammons Preston, Inc, United Kingdom). The test was performed in a sitting position in the wheelchair, with the arm in extension and in the vertical axis. The test protocol consisted of three maximal isometric contractions of 5 s, with a rest period of at least 60 s. The best of the three recordings was used for statistical analysis.

Yo-Yo 10 m Intermittent Recovery Endurance Test. Version 1 of the Yo-Yo test (YYIR1 10 m) was used as previously described by Yanci et al. (2015) and Granados et al. (2015) for WB players. The original YYIR1 test consisted of 20 m shuttle runs performed at increasing speed with 10 s of active recovery between runs until exhaustion. Considering the differences between running and propelling the wheelchair, the distance covered in the shuttle run was modified in this study to 10 m. The total distance covered (Castagna et al., 2008), a heart rate (HR) (Polar Team Sport System®, Polar Electro Oy, Finland) and lactate concentration (Lactate Pro LT-1710®, ArkRay Inc Ltd, Kyoto, Japan) were recorded. At the end of the endurance test, the subjects were also asked to rate their perceived exertion (RPE) on a 10-point category rating scale (Foster et al., 2001), presented on paper. They were asked separately for a respiratory rate of perceived exertion (RPEres) and an arm muscle rate of perceived exertion (RPEmus) as previously used in WB (Granados et al., 2015; Iturricastillo et al., 2016).

Training program and competition

During the competitive season the players competed in 16 official matches and trained twice per week. The training sessions consisted of an hour of exercise with and without the ball and the other hour was spent performing technical exercises and team tactics. The group tactics involved exercises with play situations in a more limited space and with fewer players. The training session always ended with real game situations.

Statistical analysis

The statistical analysis was carried out with the Statistical Package for Social Sciences (SPSS®

Inc, version 20.0 Chicago, IL, USA.). The results are presented as mean ± standard deviation (SD). The normality of the data was analyzed with the Kolmogorov-Smirnov tests to verify the need for parametric or non-parametric tests. A t-test for related samples was used to determine the differences between the results obtained in the pre and posttest. The delta value (ΔI) between the pre and posttest was calculated using the formula: Δ% = [(Posttest-pretest)/pretest] x 100. The effect size (d) was calculated using the method proposed by Cohen (1988). Effect sizes lower than 0.2, between 0.2-0.5, between 0.5-0.8 or greater than 0.8 were considered trivial, low, moderate or high, respectively. Statistical significance was set at $p < 0.05$.

3.4. Results

Table 1 shows the results of the body composition measurements in the Pre and Post test. The players increased their body mass ($p < 0.05$, d = 0.30, low), and there was a tendency, although it was not significant, for a decrease in the triceps ($p > 0.05$, d = -1.40, high) and in the subscapular ($p > 0.05$, d = -0.50, moderate) skin fold, together with an increase in the suprailiac skin fold ($p > 0.05$, d = 0.55, moderate) at the end of the season.

Table 1. Body composition in the pre and posttest in WB basketball players.

	Pre test	SD	Post test	SD	Δ (%)	d
Body mass (kg)	74.60	9.67	76.73*	10.11	2.86	0.30
Triceps (mm)	11.37	3.42	10.83	3.98	-4.77	-1.40
Subscapular (mm)	17.26	5.66	16.77	5.47	-2.81	-0.50
Suprailiac (mm)	15.60	6.71	16.17	6.85	3.66	0.55
Abdominal (mm)	28.94	11.49	30.20	10.04	4.34	0.38
Skin folds (∑ mm)	69.08	24.97	64.73	33.59	-6.30	-0.25

SD = standard deviation, Δ= Difference of means, d = effect size.

With regard to physical performance, Table 2 shows the results in the Pre and Post test of the players' acceleration capacity with and without the ball and their agility. There was a tendency for improvement in acceleration over 5 m ($p > 0.05$, d = 0.79, moderate) and 20 m with the ball ($p > 0.05$, d = 0.44, low). However, no differences were found in acceleration without the ball or in agility ($p > 0.05$, range d = 0.11 – 0.33, low).

As to muscular strength, no significant differences were observed in the maximal pass distance between the Pre and Post test (12.57 ± 2.10 m vs. 12.74 ± 2.41 m, $p > 0.05$, d = 0.08, trivial), or in the medicine ball throw (4.68 ± 0.54 m vs. 4.89 0.77 m, $p > 0.05$, d = 0.38, low). However, at the end of the season the players recorded better results in the handgrip test ($p > 0.05$, d = 1.26, high) than at the start of the season (Figure 1).

Table 2. Results of acceleration with and without the ball, and in the tests of change of direction ability both in the Pre and Post test, in WB players.

	Pre test (s)	Post test (s)	Δ (%)	d
Acceleration				
Without B 5 m	1.73 ± 0.06	1.71 ± 0.10	-1.15	0.33
Without B 20 m	5.16 ± 0.18	5.18 ± 0.21	0.39	0.11
With B 5 m	1.89 ± 0.19	1.74 ± 0.15	-7.84	0.79
With B 20 m	5.76 ± 0.41	5.58 ± 0.38	-3.10	0.44
Agility				
T-Test	14.35 ± 0.62	14.14 ± 0.58	-1.42	0.33
Pick up	11.85 ± 0.78	11.64 ± 0.67	-1.83	0.28

Δ = difference of means, d = effect size, Without B = without ball, With B = with ball.

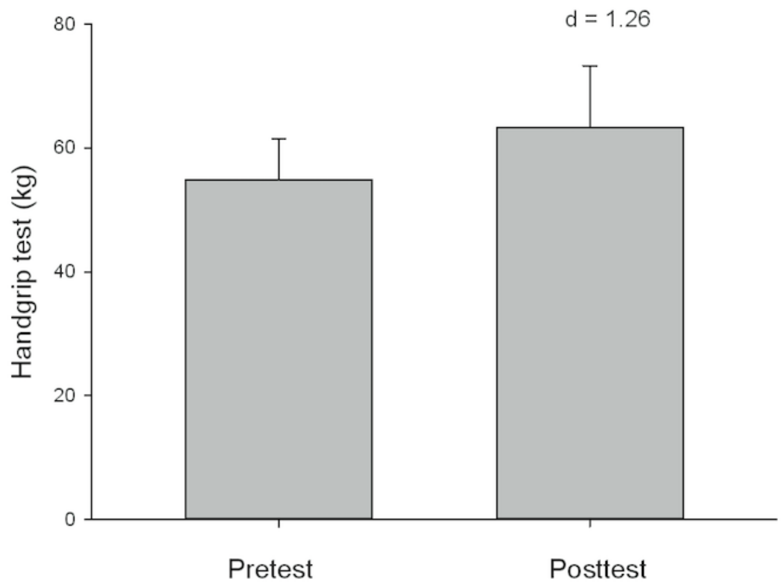

Figure 2. *Mean values (± SD) obtained in the handgrip test in both the Pre and Post test by WB players.*

With respect to the results obtained in the YYIR1, no differences were found between the Pre and Post test in lactate concentration (9.33 ± 4.05 vs. 8.70 ± 3.56 mmol·l^{-1}, $p > 0.05$, d = 0.16, trivial), or in the HRmax (184.5 ± 16.2 vs. 179.2 ± 14.1 latidos·min^{-1}, $p > 0.05$, d = 0.33, low). However, at the end of the season, the players increased their performance with regard to total distance covered, although not significantly ($p > 0.05$, d = 0.77, moderate) (Figure 2). There was also a tendency for the RPEres to be lower (6.58 ± 2.01 vs. 4.67 ± 3.14, $p > 0.05$, d = 0.95, high) but not the RPEmus (5.92 ± 2.15 vs. 5.00 ± 2.53, $p > 0.05$, d = 0.43, low) in the Post compared to the Pre test.

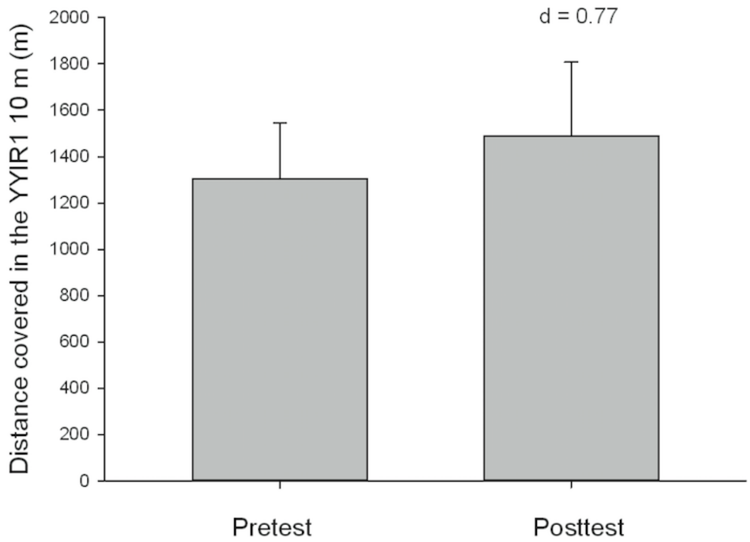

Figure 3. *Distance covered in the Yo-Yo Level 1 10 m endurance test (YYIR1 10 m) in WB players.*

3.5. Discussion

The analysis of WB players' physical fitness can provide relevant information for the determination of their sports performance (De Groot et al., 2012; Goosey-Tolfrey, 2005; Yanci et al., 2015), as it could help coaches improve the training process. The present study analyzed the evolution of body composition and physical performance in WB players during one competitive season. The results obtained regarding body composition revealed that there was an increase in body mass and a tendency for some skin folds to decrease. In relation to physical performance, the results in some physical fitness tests (5 and 20 m with the ball, distance covered in the YYIR1 10 m, and the handgrip test) were better at the end of the competitive season.

Several studies exist which have analyzed body composition in people with spinal cord injury (Collins et al., 2010; Price, 2010) and in female WB and wheelchair tennis players (Sutton et al., 2009). However, to our knowledge, there is no study that analyzes anthropometric characteristics of WB players during a competitive season. In our study, coinciding with Burke et al. (1986) who analyzed results before and after a competitive period in Australian rules football, there was a significant increase in body mass, but a decrease in skin folds. To be precise, the upper limbs showed a decrease in subcutaneous adipose tissue possibly due to a high level of activity when propelling the wheelchair, thus coinciding with the results obtained in the study by Sutton et al. (2009) where female WB players showed a lower percentage of adipose tissue in the arms than other players who did not use a wheelchair for sport. In this sense, continuous practice of WB aimed at reducing percentage of body fat could improve their physical performance and be beneficial for their health (Collins et al., 2010). In spite of the decrease in adipose tissue observed in some skin folds in the upper body (triceps and subscapular), the players in our study increased their suprailiac and abdominal skin folds at the end of the competitive season. It could possibly be interesting for WB coaches to control nutritional intake as body composition might have more likely been affected by diet rather than training and competition. A decrease in subcutaneous adipose tissue may be due to the training effects during the whole season.

Studies concerning changes in physical performance in WB during the competition period are scarce (Ayán et al., 2014) compared with able-bodied sports (Casajús, 2001; Drinkwater et al., 2005; Marques et al., 2006). The results obtained by these authors showed that physical performance in WB players revealed practically no changes during the season (trivial or low). In our case, the results were similar in both the Pre and Post test (Δ% < 1.83%, d < 0.33, trivial or low) for the sprint tests without the ball, change of direction abilities and the throwing tests. However, contrary to the results presented by Ayán et al. (2014), the players in our study did obtain better results in the sprint tests of 5 and 20 m with the ball (Δ% = 7.84%, d = 0.79 and Δ% = 3,11%, d = 0.44, respectively) and in the handgrip test (Δ% = 19.78%, d = 1.26) at the end of the season, even though they did not follow any specific training during the season to improve their strength/power. Possibly, and given that several studies on able-bodied sports had found a close association between strength and acceleration capacity (Granados et al., 2013; Rønnestad et al., 2011), and also in WB (Janssen et al., 1993; Molik et al., 2013; Turbanski and Schmidtbleicher, 2010), the absence of specific training aimed at improving strength could have influenced the lack of improvements in acceleration capacity, change of direction ability and throwing. It would therefore be interesting to analyze if including specific strength/power training sessions could produce improvements in the physical performance of WB players during the season.

Aerobic capacity has also been studied in WB by different authors (Vanlandewick et al., 1999; Goosey-Tolfrey et al., 2008) due to its importance for the sport. In spite of the fact that field tests to measure changes in aerobic capacity have been widely applied in able-bodied team sports, only few papers have studied this quality in WB (Ayán al., 2015). Our results indicate that there was an improvement in the YYIR1 test at the end of the season, although it was not significant (Δ% = 14.73%, d = 0.77). Furthermore, the players who participated in our study showed lower levels of lactate concentration in the Post test (9.33 ± 4.05 $mmol \cdot l^{-1}$ vs. 8.70 ± 3.56 $mmol \cdot l^{-1}$). In this sense, WB players recorded a better performance in the YYIR1 and had better physiological responses at the end of the season; thus, the improvement in the YYIR1 test at the end of the season could indicate an improvement in aerobic capacity. There was also an improvement in their RPE, especially their RPEres (Δ% = 29.03%, d = 0.95), therefore, this fact confirms the better performance in the aerobic test at the end compared to the beginning of the season. These results are quite similar to those obtained by Ayán et al. (2012) as the latter state that they did not observe important changes in the multi stage fitness test (MSFT) at three different time points in the WB season (p = 0.683; ∆% = 10.40). Possibly the nature and typology of the tests used, the internal and external load in the training sessions and matches, as well as body composition at the respective moment could have influenced the obtained results. In this sense, it would be interesting to study the effects of implementing specific programs to improve physical performance in WB and to establish more test sessions to monitor the effects of the programs followed.

The obtained results should be interpreted with caution due to some important limitations of the study. First of all, nutritional intake during the whole season was not controlled, and the body composition changes might have been due to diet rather than training and competition. Moreover, a control group could have provided us with exact data on the training effects for physical fitness, which is why it would be interesting for future research to include one.

3.6. Conclusions

In our study the WB players showed changes during the season in some variables of body composition and physical fitness, i.e. in acceleration capacity over 5 and 20 m with the ball, strength, the handgrip test, and the total distance covered in the endurance test. However, no differences were observed in acceleration capacity without the ball, change of direction ability, or explosive strength. Coaches of WB teams should consider the need to implement additional specific training sessions to improve these abilities in WB players.

4. LAUGARREN KAPITULUA

Objective and subjective methods for quantifying training load in wheelchair basketball small-sided games

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4.1. Abstract

Purpose: the aim of the present study was to analyze the training load in wheelchair basketball small-sided games and determine the relationship between heart rate (HR) based training load and perceived exertion (RPE) based training load methods among small-sided games bouts. **Methods:** HR-based measurements of training load included Edwards' training load and Stagno's training impulses ($TRIMP_{MOD}$) while RPE-based training load measurements included cardiopulmonary (session RPEres) and muscular (session RPEmus) values. Data were collected from 12 wheelchair basketball players during five consecutive weeks. **Results:** The total load for the small-sided games sessions was 67.5 ± 6.7 and 55.3 ± 12.5 arbitrary units in HR-based training load (Edwards' training load and $TRIMP_{MOD}$), while the RPE-based training loads were 99.3 ± 26.9 (session RPEres) and 100.8 ± 31.2 arbitrary units (session RPEmus). Bout-to-bout analysis identified greater session RPEmus in the third ($p < 0.05$; ES = 0.66, moderate) and fourth bouts ($p < 0.05$; ES = 0.64, moderate) than in the first bout, but other measures did not differ. Mean correlations indicated a trivial and small relationship among HR-based and RPE-based training loads. **Conclusions:** It is suggested that HR-based and RPE-based training loads provide different information, but these two methods could be complementary because one method could help us to understand the limitations of the other.

Keywords: *Para-sport, training tasks, rating of perceived exertion, heart rate, training load.*

4.2. Introduction

Over the last decade, a new approach to improving team sport athletes' fitness has been developed in the form of game-based conditioning (Klusemann et al., 2012). According to these authors (Klusemann et al., 2012), small-sided games provide greater transfer of physiological adaptations as training simulates the movement patterns that athletes perform in competition. Moreover, this type of training allows simultaneous technical, tactical and physical training, and also seems to be a task that improves motivation and enjoyment for athletes over interval training (Los Arcos et al., 2015b). However, we do not know how these psychological responses could be transferred to competition. Although there are several studies on small-sided games in able-bodied team sports such as football (Campos-Vazquez et al., 2015; Hill-Haas et al., 2011), handball (Buchheit et al., 2009; Corvino et al., 2014) and basketball (Castagna et al., 2011; Delextrat & Kraiem, 2013; Sampaio et al., 2009), few studies have investigated in adapted team sports (Yanci et al., 2014). In able-bodied basketball, for example, small-sided games have been extensively analyzed (Castagna et al., 2011; Delextrat & Kraiem, 2013; Sampaio et al., 2009), but there are practically no studies on wheelchair basketball (Yanci et al., 2014).

To quantify training load in basketball, heart rate (HR) has been used (Delextrat & Kraiem, 2013; Sampaio et al., 2009). Nevertheless, because of limitations in quantifying load by mean HR and maximal HR or peak HR, several authors have proposed other methods that improve assessments of training demand (Edwards, 1993; Stagno et al., 2007). These authors quantified demands of interval training by summating HR zones and giving a final value for each training session or training task. In addition, in recent decades, the HR has been supplemented by a subjective measure of training load such as an athlete's overall session rating for perceived exertion (RPE) (Foster et al., 2001). Many studies have analyzed overall RPE in able-bodied team sports (Coutts et al., 2009), but in spite of the increasing number of investigations into subjective measures of internal load in adapted physical activity and sports (Al-Rahamned & Eston, 2011; Paulson et al., 2015; Qi, Ferguson-Pell et al., 2015), to the best of our knowledge no studies have examined RPE and small-sided games (or intermittent high-intensity training tasks).

Various studies have validated subjective methods in different team sports (Foster et al., 2001; Impellizzeri et al., 2004) and especially in basketball (Manzi et al., 2010; Scanlan et al., 2014). Strong relationships between objective and subjective methods have been reported. Manzi et al. (2010) reported high correlations in basketball training tasks between objective and subjective methods (r = 0.69 to 0.85 for all participants). Scanlan et al. (2014) reported similar findings; the subjective method correlated with the objective method (r = 0.80 to 0.89). However, little is known about the association between HR and RPE methods in intermittent activities in wheelchair basketball players (Iturricastillo et al., 2016a). These authors showed moderate correlations between HR-based methods and RPE-based methods (r = 0.63 – 0.67, R^2 = 0.40 –

0.45, P < 0.001) in wheelchair basketball matches, but there were no relationships in players with polio and high SCI (complete T1-T2). It is well known that players with high SCI cannot provoke high HR values (Goosey-Tolfrey, & Leicht, 2013). Thus, it would be useful to know if RPE-based methods are valid in wheelchair basketball for quantifying responses to intermittent high-intensity exercise such as a small-sided games task. The ability to monitor exercise intensity during wheelchair basketball training can be used to provide important feedback to the coach about the potency of training stimuli applied to players.

Thus, the aim of the present study was to analyze the training load in wheelchair basketball small-sided games by means of objective (i.e. HR) and subjective (i.e. RPE) methods and to determine the evolution of the training load between small-sided games bouts. The second aim of the study was to determine the relationship between session RPE training load and HR-based training load and so evaluate the use of session RPE training load for assessing global exercise intensity during wheelchair basketball-specific small-sided games.

4.3. Material and methods

Participants

Twelve Spanish First Division wheelchair basketball players (age 31.0 ± 9.3 years, injury time 19.1 ± 13.5 years, training experience 8.6 ± 7.8 years, peak HR 177.7 ± 13.5 beats·min^{-1}) participated in the study. The inclusion criterion for the participants in the study was possession of a valid licence from the Spanish Federation of Sports for People with Physical Impairments. The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF) (Table 1). Before their involvement, all participants gave written informed consent after a detailed written and oral explanation of the potential risks and benefits from participation in this study had been given, as outlined in the Declaration of Helsinki (2013). The participants had the option to withdraw from the study at any time. The Ethics Committee of the University of the Basque Country approved the study.

Procedures

The study was conducted over five consecutive weeks during the competitive period (November – December, season 2013-2014), when the team had five matches (fixture 2, 3, 4, 5, and 6) during these weeks. The players undertook two training sessions and one official match per week. However, not all played every match or the same duration. Furthermore, none of these players was taking part in additional strength and conditioning sessions at the time of the study. The HR- and RPE-based training load of a full-court 4 *vs.* 4 small-sided games were quantified. The small-sided games were part of the training sessions, so data were collected during the five consecutive Tuesdays at the same time of day (8–9 PM) and with at least 48 hr rest between sessions. The small-sided games were performed on a basketball court (15 x 28 m). The duration (4 x 4 min separated by 2 min of passive recovery) of each small-sided games was strictly controlled as implemented by others (Dellal et al., 2011) and in wheelchair basketball (Yanci et al., 2014). The teams were balanced for impairment and according to the IWBF functional classification. Thus, players with SCI were intermixed with players without SCI. Moreover, there were no player changes during the same session. A total of 32 individual small-sided games sessions met all requirements, thus data from 128 individual bouts were included in the analysis.

Table 1. Wheelchair basketball players' characteristics.

Player	Injury	Age (years)	IWBF classification	Injury time (years)	Injury time (years)
P1	Spina Bífida (L1)	16	1	16	2
P2	Spinal Cord Injury (T1-T2)	36	1	34	20
P3	Spinal Cord Injury (T12-L3)	42	1	18	18
P4	Spinal Cord Injury (T3)	19	1	12	1
P5	Spinal Cord Injury (incomplete, C5-C6)	35	3	30	7
P6	Spinal Cord Injury (T10)	30	3	2	2
P7	Viral Disease (polio)	35	3.5	33	21
P8	Osteoarthritis congenital	40	4	40	2
P9	Amputation	35	4	28	2
P10	Hip labral tear	18	4.5	2	4
P11	Knee injury	41	4.5	9	9
P12	Knee injury	25	4.5	5	15
Sample (n = 12)		31 ± 9.3	–	19.1 ± 13.5	8.6 ± 7.8

IWBF = International Wheelchair Basketball Federation, P = player.

Endurance test. To obtain the individual peak heart rate of each player, all completed a 10 m Yo-Yo intermittent recovery test, level 1, as previously used in wheelchair basketball (Yanci et al., 2015), one week before the competition period. This endurance test has good reproducibility (Intraclass Correlation Coefficient = 0.83 – 0.94 and coefficients of variation from 2.6% to 7.2%) (Yanci et al., 2015). Pushing speeds were dictated in the form of audio cues broadcast by a pre-programmed computer. The test was considered to have ended when the participant failed twice to reach the front line in time (objective evaluation) or felt unable to cover another shuttle at the dictated speed (subjective evaluation). In any case, all players were accustomed to the field-testing procedures as they were part of their usual fitness assessment programme. During the test, HR was continuously monitored at 1 s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). The peak HR was determined from the highest value obtained by each player either in the YYIR1 or the small-sided games.

Table 2. Heart rate and rating of perceived exertion responses to the modified Yo-Yo intermittent recovery test 1 (modified YYIR1) and peak HR values during small-sided games.

Player	Modified YYIR1 (peak HR) (beat·min^{-1})	Peak HR during SSG (beat·min^{-1})	Percentage of peak HR reached during SSG (%)	RPEres (Arbitrary Units)	RPEmus (Arbitrary Units)
1	180	181	100.6	9.5	9
2	154	131	85.1	6	9
3	191	180	94.2	5	4
4	188	190	101.1	6	8
5	169	168	99.4	8	9
6	159	153	96.2	8	8
7	176	180	102.3	4	4
8	179	172	96.1	7	5
9	185	175	94.6	9	7
10	203	193	95.1	2	8
11	169	179	105.9	9	9
12	182	184	101.1	8.5	9
Sample (n = 12)	177.9 ± 13.7	173.8 ±17.0	97.6 ± 5.4	6.8 ± 2.3	7.4 ± 2.0

HR = heart rate; SSG = small-sided games; RPEres = Cardiopulmonary perceived exertion; RPEmus = Muscular perceived exertion.

Determination of small-sided games training load. We determined the training load (arbitrary units) for each player during each small-sided games by four methods used previously in team sports and in wheelchair basketball (Iturricastillo et al., 2016). Specifically, two HR-based methods, Edwards (1993) and $TRIMP_{MOD}$ (Stagno et al., 2007), and two other RPE-based methods, perceived cardiopulmonary training load (session RPEres) and perceived muscular training load (session RPEmus) (Iturricastillo et al., 2016; Los Arcos et al., 2014a; Los Arcos et al., 2015a), were used to quantify training load. The HR was continuously monitored throughout the small-sided games at 1 s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). Duration of play was investigated, so no rest times were included in this study.

Edwards' training load method. Edwards' (1993) method includes the total volume of training and considers five zones of intensity. The calculation was performed for each session by multiplying the accumulated time (min) in each HR zone for a value assigned to each intensity zone (90–100 % peak HR = 5, 80–89 % peak HR = 4, 70–79 % peak HR = 3, 60–69 % peak HR = 2, 50–59 % peak HR = 1), and finally summarizing the results (Edwards, 1993; Iturricastillo et al., 2016).

$TRIMP_{MOD}$ method. TRIMP calculation was also performed as proposed by Stagno et al. (2007). The training load is determined by calculating the result of multiplying the training duration (min) in each of the current zones by the weighting factor for each zone (93–100 % peak HR = 5.16;

86–92 % peak HR = 3.61; 79–85 % peak HR = 2.54; 72–78 % peak HR = 1.71; 65–71 % peak HR = 1.25), and finally summarizing the results.

Perceived exertion-based methods. The 10-point scale proposed by Foster et al. (2001) was administered at the end of each bout. Players responded separately about the cardiopulmonary RPE and the muscle RPE (Iturricastillo et al., 2016; Paulson et al., 2015; Qi et al., 2015). The specific question asked to the wheelchair basketball players for the RPE was: *How hard was this bout for you in relation to cardiopulmonary or muscular exertion?* Furthermore, other players were not aware of the RPE scores. Afterwards, RPEres and RPEmus values were multiplied by the total duration of the small-sided games bouts (min), according to Foster et al. (2001), to quantify the RPE-derived training load exposed as session RPEres and session RPEmus. Players were informed about the 10-point scale before the data collection for this study for a month and it was used in all types of training sessions and matches.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used for calculating the mean and standard deviations (SD). Data were screened for normality of distribution and homogeneity of variances using Shapiro-Wilk and Levene's, respectively. This test showed equal variance, so parametric tests were used thereafter. Differences between small-sided games bouts in each dependent variable, including Edwards' training load, $TRIMP_{MOD}$, session RPEres and session RPEmus, were analyzed using a one-way within-participants ANOVA, followed by Bonferroni's pos hoc test. The effect size (ES) was calculated using the method proposed by Cohen (1988). Effect sizes lower than 0.2, between 0.2-0.5, between 0.5-0.8 or greater than 0.8 were considered trivial, small, moderate, or large, respectively. The relationships between HR-based training load methods and RPE-based training load scores were assessed using Pearson's product moment correlation (r), as well as the confidence limits (CL, 90%) and the coefficient of determination (R^2). The following scale of magnitudes was used to evaluate correlation coefficients: < 0.1, trivial; = 0.1 – 0.3, small; < 0.3 – 0.5, moderate; < 0.5 – 0.7, large; < 0.7 – 0.9, very large; and < 0.9 – 1.0, almost perfect (Hopkins et al., 2009). Moreover, the coefficient of variation (V%) about regression was calculated using the formula: V% = [Standard error of the estimate / mean of the outcome measure] x 100 (Winter & Hamley, 1976). The $p < 0.05$ criterion was used for establishing statistical significance.

4.4. Results

The training load for the small-sided games session (i.e. the total of the 4 bouts) was 67.5 ± 6.7 arbitrary units and 55.3 ± 12.5 arbitrary units in HR-based training load (Edwards' training load and $TRIMP_{MOD}$, respectively). Moreover, the perceived training loads were 99.3 ± 26.9 arbitrary units (session RPEres) and 100.8 ± 31.2 arbitrary units (session RPEmus). In the bout-to-bout analysis, greater perceived muscular training load occurred in the third ($p < 0.05$; ES = 0.66, moderate) and fourth bouts ($p < 0.05$; ES = 0.64, moderate) than in the first bout (Table 3). However, there were no differences among bouts in HR-based training load ($p > 0.05$; range ES = -0.12 to 0.39, trivial to small) and session RPEres ($p > 0.05$; range ES = -0.02 to 0.51, trivial to moderate).

The mean correlations indicated a very poor relationship between HR-based training load and differential RPE-based training load. In addition, according to individual correlations, there were high correlations between HR-based training load and RPE-based training load in player 6 (r = 0.58, large; R^2 = 0.34; V% = 7.1%; $p < 0.05$; Injury = SCI T10; IWBF classification = 3) and player 7 (r = 0.48 and 0.62, moderate and large; R^2 = 0.39 and 0.23; V% = 6.1 and 14.7%; $p < 0.05$; Injury = polio; IWBF classification = 3.5), but there were none in most players (Table 4). There were high correlations between Edwards' training load and Stagno's $TRIMP_{MOD}$, but not in player 2 (Injury = SCI T1-T2; IWBF classification = 1), player 7 (Injury = Polio; IWBF classification = 3.5), player 11 (Injury = knee injury; IWBF classification = 4.5) and player 12 (Injury = knee injury; IWBF classification = 4.5). As regards session RPEres and session RPEmus, there were high correlations in five individuals (two players with SCI and three players with Non-SCI).

According to the wheelchair basketball team observations (Table 5), there were very high correlations between Edwards' and Stagno's $TRIMP_{MOD}$ training loads in every bout (r range = 0.94;±0.04 to 0.98;±0.03; range R^2 = 0.81 to 0.95; range V% = 2.3 to 3.9%; $p < 0.001$) and in the total of the small-sided games (r = 0.96;±0.01; R^2 = 0.92; V% = 3.1%; $p < 0.001$). Moreover, there were high correlations between session RPEres and session RPEmus in every bout (r range = 0.74;±0.14 to 0.78;±0.12; range R^2 = 0.55 to 0.61; range V% = 16.2 – 23.5%; $p < 0.001$) and in the total of the small-sided games (r = 0.78;±0.06; R^2 = 0.60; V% = 18.5%; $p < 0.001$). Nevertheless, there were trivial or small correlations between HR-based training load and RPE-based training load methods in any bout or in the total of the small-sided games (range r = -0.30;±0.27 to 0.26;±0.28; range R^2 = 0.00 to 0.09; range V% = 10.0 – 29.9%; $p > 0.05$).

Table 3. Heart rate-based and perceived-based training load models during 4 *vs.* 4 small-sided games.

Method	Bout 1 (32 individual bouts)	Bout 2 (32 individual bouts)	Bout 3 (32 individual bouts)	Bout 4 (32 individual bouts)	Total 4x4 SSG
Edwards' training load (arbitrary units)	16.5 ± 1.9 (24.5)	16.9 ± 1.7 (25)	17.1 ± 1.8 (25.4)	17.0 ± 1.9 (25.1)	67.5 ± 6.7
$TRIMP_{MOD}$ (arbitrary units)	13.1 ± 3.3 (23.7)	13.9 ± 3.4 (25.1)	14.4 ± 3.4 (25.9)	14.0 ± 3.5 (25.3)	55.3 ± 12.5
Session RPEres (arbitrary units)	22.3 ± 7.7 (22.4)	24.8 ± 7.3 (24.9)	26.2 ± 6.6 (26.4)	26.1 ± 7.1 (26.3)	99.3 ± 26.9
Session RPEmus (arbitrary units)	21.4 ± 8.9 (21.1)	25.1 ± 8.0 (24.9)	27.3 ± 8.0* (27.1)	27.1 ± 8.2* (26.9)	100.8 ± 31.2

*Values are means ± SD; Values within brackets show % of the total training load. $TRIMP_{MOD}$ = Modified training impulse; session RPEres = perceived cardiopulmonary training load; session RPEmus = perceived muscular training load. *$p < 0.05$ significant differences compared to bout 1.*

Table 4. Individual correlations (±90% confident limit, CL) between heart rate-based and perceived exertion based training load during 4 *vs*. 4 small-sided games.

Player	**Edwards'**		**TRIMP$_{MOD}$**		**Edwards**	**Session RPEres**
	Session RPEres	**Session RPEmus**	**Session RPEres**	**Session RPEmus**	**TRIMP$_{MOD}$**	**Session RPEmus**
	r ;±CL (**R^2**) **V (%)**	**r** ;±CL (**R^2**) **V (%)**	**r** ;±CL (**R^2**) **V (%)**	**r** ;±CL (**R^2**) **V (%)**	**r** ;±CL (**R^2**) **V (%)**	**r** ;±CL (**R^2**) **V (%)**
1	-0.12;± 0.49 (0.015) 11.08%	0.05;± 0.50 (0.002) 11.13%	-0.11;± 0.49 (0.013) 24.16%	0.10;± 0.50 (0.009) 24.24%	0.99;± 0.0*** (0.973) 1.82%	0.73;± 0.27** (0.538) 7.52%
2	-0.55;± 0.28 (0.300) 1.8%	0.90;± 0.08 (0.817) 0.96%	-0.88;± 0.10 (0.773) 0.75%	0.17;± 0.37 (0.030) 1.50%	0.13;± 0.37 (0.018) 2.12%	-0.46;± 0.31 (0.207) 9.29%
3	-0.40;± 0.56 (0.156) 5.30%	-0.34;± 0.58 (0.112) 5.42%	-0.61;± 0.46 (0.372) 8.11%	-0.37;± 0.57 (0.136) 9.51%	0.88;± 0.20 (0.765) 2.80%	0.91;± 0.16 (0.828) 4.65%
4	0.05;± 0.63 (0.002) 5.39%	-0.69;± 0.40 (0.478) 3.88%	0.16;± 0.62 (0.025) 11.14%	-0.69;± 0.40 (0.476) 8.18%	0.97;± 0.06* (0.933) 1.40%	0.58;± 0.48 (0.333) 6.90%
5	0.53;± 0.88 (0.275) 5.05%	0.68;± 0.83 (0.461) 4.34%	0.53;± 0.88 (0.276) 11.67%	0.68;± 0.83 (0.468) 10.00%	0.96;± 0.35*** (0.920) 1.70%	0.97;± 0.29*** (0.945) 7.65%
6	0.58;± 0.36* (0.338) 7.13%	0.50;±0.40 (0.247) 7.65%	0.57;±0.37 (0.324) 16.69%	0.44;±0.42 (0.196) 18.19%	0.97;±0.04*** (0.940) 2.17%	0.55;±0.38 (0.302) 7.62%
7	0.43;± 0.90 (0.185) 7.03%	0.62;± 0.83** (0386) 6.10%	0.48;± 0.89* (0.235) 14.66%	0.66;± 0.84** (0.429) 12.68%	0.97;± 0.29*** (0.937) 4.39%	0.80;± 0.74***(0.634) 21.14%
8	0.36;± 0.38 (0.134) 9.54%	-0.01;± 0.43 (0.000) 10.26%	0.54;± 0.32 (0.288) 18.74%	0.23;± 0.41 (0.054) 21.64%	0.91;± 0.09*** (0.827) 4.31%	0.14;± 0.42 (0.018) 16.78%
9	0.43;± 0.43 (0.187) 10.11%	0.29;± 0.47 (0.083) 10.77%	0.40;± 0.44 (0.158) 22.97%	0.30;± 0.46 (0.092) 23.93%	0.99;±0.01*** (0.975) 1.64%	0.57;± 0.37 (0.320) 8.69%
10	0.27;± 0.60 (0.075) 3.79%	0.33;±0.58 (0.107) 3.72%	0.34;±0.58 (0.118) 10.69%	0.17;±0.62 (0.027) 11.23%	0.82;±0.28*** (0.675) 2.22%	0.43;±0.55 (0.182) 14.82%
11	0.18;± 0.37 (0.033) 2.18%	-0.02;±0.38 (0.001) 2.23%	-0.08;±0.38 (0.007) 8.76%	-0.15;±0.37 (0.021) 8.71%	0.21;±0.36 (0.046) 2.18%	0.73;±0.19** (0.529) 5.00%
12	-0.20;± 0.92 (0.040) 2.45%	-0.29;± 0.92 (0.085) 2.40%	0.15;± 0.93 (0.021) 7.51%	0.44;± 0.90 (0.190) 6.85%	-0.28;± 0.92 (0.079) 2.40%	0.91;± 0.56** (0.828) 4.25%
Mean	**0.13;± 0.29**	**0.17;± 0.29**	**0.12;± 0.29**	**0.17;± 0.29**	**0.71;± 0.15**	**0.57;± 0.21**

*P = player; Min = minimun value; Max = maximun value; TRIMPMOD = Modified training impulse; Session RPEres = perceived cardiopulmonary training load; Session RPEmus = perceived muscular training load; r = Pearson coefficient; R2 = coefficient of determination; V = variation about regression. *p < 0.05 and **p < 0.01 significant individual correlations.*

Table 5. Total correlations (±90% confident limit, CL) in each bout between heart rate-based and perceived training load models during 4 *vs*. 4 small-sided games.

Training load methods		Bout 1 **r** ;±CL (**R^2**) **V (%)**	Bout 2 **r** ;±CL (**R^2**) **V (%)**	Bout 3 **r** ;±CL (**R^2**) **V (%)**	Bout 4 **r** ;±CL (**R^2**) **V (%)**	Total 4x4 SSG **r** ;±CL (**R^2**) **V (%)**
Edwards'	*Session RPEres*	0.15;±0.29 (0.022) 11.31%	0.22;±0.28 (0.048) 10.02%	0.26;±0.28 (0.066) 10.51%	-0.17;±0.29 (0.028) 11.16%	0.13;±0.14 (0.017) 10.72%
	Session RPEmus	0.16;±0.29 (0.026) 11.25%	0.09;±0.29 (0.008) 10.20%	0.05;±0.30 (0.003) 10.86%	-0.30;±0.27 (0.091) 10.64%	0.03;±0.15 (0.001) 10.78%
$TRIMP_{MOD}$	*Session RPEres*	0.18;±0.29 (0.034) 29.90%	0.16;±0.29 (0.027) 24.35%	0.24;±0.28 (0.055) 23.66%	-0.15;±0.29 (0.022) 24.75%	0.13;±0.14 (0.018) 24.33%
	Session RPEmus	0.13;±0.29 (0.017) 25.55%	0.05;±0.30 (0.002) 24.71%	0.04;±0.30 (0.002) 24.36%	-0.29;±0.27 (0.082) 23.97%	0.02;±0.15 (0.000) 24.55%
Edwards	$TRIMP_{MOD}$	0.94;±0.04***(0.881) 3.93%	0.95;±0.03***(0.903) 3.20%	0.98;±0.03***(0.955) 2.34%	0.96;±0.03***(0.930) 2.99%	0.96;±0.01***(0.917) 3.14%
Session RPEres	*Session RPEmus*	0.74;±0.14***(0.552) 23.46%	0.75;±0.14***(0.565) 19.59%	0.78;±0.12***(0.606) 16.15%	0.78;±0.12***(0.613) 17.19%	0.78;±0.06***(0.601) 18.53%

*TL = training load; $TRIMP_{MOD}$ = Modified training impulse; Session RPEres = perceived cardiopulmonary training load; Session RPEmus = perceived muscular training load; r = Pearson coefficient; R^2 = coefficient of determination; V = variation about regression. ***p < 0.001 significant correlations.*

4.5. Discussion

The training load has been analyzed in many team sports, including relationships between objective and subjective methods. The RPE-based training load method has been widely correlated with the HR-based training load score in many sport-training tasks (Impellizzeri et al., 2004; Manzi et al., 2010; Scanlan et al., 2014). Nevertheless, there have been few studies in relation to wheelchair basketball in spite of the importance of quantifying the load in an adapted team sport (Iturricastillo et al., 2016a). Thus, the current study described the training load and investigated the relationship between HR-based training load and RPE-based training load methods in wheelchair basketball players during small-sided games. The main findings of this study were: a) HR-based training load and session RPEres were stable during small-sided games bouts while session RPEmus increased in the final bouts; b) there were no correlations in almost all the individuals between objective and subjective methods. Thus, the session RPEres and session RPEmus provide useful information to the objective values, however, caution should be applied when using and interpreting only one of these methods during wheelchair training tasks.

The bout-to-bout analyses (RPE-based training load and HR-based training load), the objective training load and session RPEres were stable from 1 to 4 bouts while the session RPEmus was greater in the third and fourth bouts than in the first one. This might arise from wheelchair basketball small-sided games characteristics (such as the intermittent high-intensity nature and the strength implications). Similar results were reported by Sampson et al. (2015) for rugby league players whose overall perceived effort was greater in the last bout than in the first bout in different types of small-sided games. Moreover, in only two out of eight types of small-sided games were differences in HR response (all of them in low HR zones) (Sampson et al., 2015). Methods based on the determination of cardiovascular capacities are insensitive to muscular fatigue, so they could not detect it. Similar results were reported by Los Arcos et al. (2014a) in soccer players at the end of an official soccer match where session RPEmus was greater than session RPEres. Moreover, the mean session RPEmus match load in wheelchair basketball was higher (2.87%) than for session RPEres (Iturricastillo et al., 2016a). Thus, our higher results for session RPEmus in the last bouts of the small-sided games suggest that at the end of small-sided games, wheelchair basketball players have greater subjective perception of strain from their peripheral exercising muscles and joints than perceived tachycardia or breathing. This might be related to the size of muscle mass, hence, it would be informative to study how muscle mass or types of muscle fibre are related to subjective muscular perception during small-sided games. It would also be useful to determine fatigue at the muscle level in the upper limbs during game-based training tasks in wheelchair basketball. Session RPEmus could be an indicator that coaches should consider to quantify muscle fatigue in wheelchair basketball athletes.

The recent literature concerning the relationship between subjective and objective training load in different adapted sports is scarce (Iturricastillo et al., 2016a; Paulson et al., 2015), while in able-bodied team sports these relationships are widely studied (Impellizzeri et al., 2004; Los Arcos et al., 2014a; Scanlan et al., 2014). Individual correlations of our study between objective and subjective methods showed that there was a wide variety among all of them (r range = -0.88;±0.10 to 0.90;±0.08; range V% = 0.8 – 24.2%). These relationships are similar to those found by Campos-Vazquez et al. (2015) in soccer players, where a low relationship was observed between $TRIMP_{MOD}$ and RPE-based training load (range r = 0.17 to 0.51; average r = 0.35). Similar but higher relationships were observed between Edwards' training load and RPE-based training load (range r = 0.40 to 0.67). In any case, there are many more papers on able-bodied sports supporting the relationship between both methods than denying that there is one (Impellizzeri et al., 2004; Manzi et al., 2010; Scanlan et al., 2014). Nevertheless, in wheelchair basketball, Iturricastillo et al. (2016a) did not report a high relationship between HR-based match load and session RPE match load in all players in relation to injury type. Moreover, in the present study, the relationships between the HR-based training load group and the RPE-based training load group in each bout were trivial or small. Some studies have observed that the maximal HR in people with high-level SCI (lesion above T1–T5) could be impaired, such as lowered maximal heart rates of about 100–135 beats per minute (Goosey-Tolfrey & Leicht, 2013). This could lead us to think that the lack of a relationship between RPE and HR could be due to the impairment itself. However, Paulson et al. (2013) showed very large correlations between physiological markers and subjective methods in eight male wheelchair-dependent participants with a cervical SCI at C5/6 (VO_2 and muscular RPE, r = 0.91; VO_2 and cardiopulmonary RPE, r = 0.88; VO_2 and overall RPE, r = 0.90). Other authors also found moderate to high relationships between objective and subjective methods in laboratory environments (Al-Rahamned & Eston, 2011; Paulson et al., 2013; Qi et al., 2015). In this sense, the intermittent high-intensity nature with a high anaerobic component and the characteristics of the small-sided games with muscle stress generated by stopping and going and changes of direction in the small-sided games, compared to the incremental testing of other studies, as well as the impairment of functional ability, could be the reason for the differences found. Therefore, the results revealed that the RPE-based training load methods could not explain the HR-based training load, so both methods might be measuring different internal loads in small-sided games. Thus, due to the disparity of affectation among wheelchair basketball players resulting in heterogeneity of IWBF classification scores, a different trend has been observed in each player according to the correlations between objective and subjective methods. For this reason, it might be recommendable for coaches to use both methods because both of them could provide relevant information.

This study analyzed the training load of small-sided games by means of objective and subjective methods, as well as the correlations between them. However, the low sample precluded us from analyzing the results with guarantees according to the impairment or functional class. For this reason, it could be very interesting to study if all players have similar training load and correlations attending objective and subjective methods in relation to impairment (i.e. SCI and Non-SCI) and functional class (1-1.5, 2-2.5, 3-3.5 and 4-4.5) during different training tasks to determine the validity of objective and subjective methods in wheelchair basketball.

4.6. Conclusions

The training load in wheelchair basketball small-sided games was constant between bouts for HR-based methods and session RPEres, but not in session RPEmus. Therefore, even though the cardiovascular load seems to be constant between bouts, the session RPEmus could indicate muscle fatigue in this task. Thus, the coaches should add the quantification of the muscle load by session RPE as a complement of the HR monitoring in order to control its development during small-sided games.

The present results do not support the relationship between objective and subjective methods for quantifying high intensity intermittent training tasks in wheelchair basketball players. Therefore, HR-based training load and RPE-based training load could provide different information, so the current training quantification should be considered independently. Nevertheless, the two methods might be complementary and one method could help us to understand the limitations of the other. Likewise, the individual correlations differ among players, possibly due to different impairment and IWBF classification scores, so further studies on the influence of injury correlations between HR and RPE methods are suggested.

5. BOSTGARREN KAPITULUA

Physiological responses between players with and without spinal cord injury in wheelchair basketball small-sided games

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5.1. Abstract

Purpose: This study examined physiological responses in commonly used small-sided games (SSG) in well experienced wheelchair basketball (WB) players with Spinal Cord Injury (SCI) and without Spinal Cord Injury (Non-SCI). **Methods:** The team was divided into an SCI group (n=6) and a Non-SCI group (n=6). Absolute and relative heart rate (HR), along with tympanic temperature and perceived exertion (RPE) were recorded for both groups. **Results:** The two groups attained different absolute HR values for the same SSG. However, no significant differences were observed in relative HR between groups (%HRmean, %HRpeak, and the percentage of the time spent in each HR zone: low, moderate, high, and maximal) nor in tympanic temperature. Moreover, in relation to the bout evolution analysis (4 repetitions of 4 minutes) the Non-SCI group significantly increased ($p < 0.05$) absolute HRmean and HRpeak during bouts while the SCI group maintained them constant. Furthermore, the variations in the percentage of the time spent in each HR zone only were observed in the Non-SCI group. **Conclusion:** In spite of the Non-SCI group attaining higher absolute HR values, the SCI and Non-SCI groups may have similar HR relative values during a specific WB training task. However, the SCI group reported significantly higher values in respiratory RPE in the last bout than the Non-SCI group for the same SSG.

Keywords: *Adapted sport, exercise load, heart rate, perceived exertion***,** *temperature, spinal cord injury*

5.2. Introduction

Physiological demands in team sports have been analyzed in many studies during matches (Ben Abdelkrim et al., 2007; Scanlan et al., 2012) and training sessions (Hill-Haas et al., 2011; Köklü et al., 2011). However, there is a lack of information about the time spent performing activities specific to wheelchair basketball (WB) and the physiological demands associated with this sport (Bloxham et al., 2001). It is important to understand the physiological competitive sporting requirements (Croft et al., 2010; Iturricastillo et al., 2016a), as studied in able-bodied sports, to ensure that training reflects the demands of the sport. For this reason, heart rate (HR) monitors are mainly used to determine the exercise intensity of a training session or a competition in WB (Bloxham et al., 2001; Coutts, 1988; Croft et al., 2010; Schmid et al., 1998). In addition, many studies are available on the metabolic and cardiovascular responses to wheelchair and arm ergometry (Vanlandewijck et al., 1999), but despite attempts to improve and optimize current training methods and sport-specific training (Bloxham et al., 2001), more studies are required focused on the physiological demands of WB in specific training tasks.

Small-sided games (SSG) are specific training tasks with the goal of reducing interactions and increasing the ratio of players' participation in decision making, but preserving basic variability properties from the game (Hoffmann et al., 2014). That is why, nowadays, SSG are becoming increasingly popular in many team sports, such as soccer (Hill-Haas et al., 2011; Köklü et al., 2011), rugby (Foster et al., 2010), Australian football (Davies et al., 2013) and specially in basketball (Delextrat & Kraiem, 2013; Sampaio et al., 2009). Essentially, SSG represent a highly intense game, either specific or non-specific to the sport, which focuses on some aspect that the coach is attempting to improve (Hoffmann et al., 2014). The supposition that SSG may simulate the physiological workloads and intensities commensurate with actual match play while also developing technical and tactical proficiency has led to its popularity as a training modality in the applied and scientific domain within recent years. Moreover, SSG appear to replicate movement demands and require players to make decisions under pressure and in conditions of fatigue (Hill-Haas et al., 2011). Nevertheless, only one study has analyzed the physiological responses in SSG in WB (Yanci et al., 2014).

In many of the papers cited above, HR was a commonly used tool to describe physiological responses during matches (Ben Abdelkrim et al., 2007; Coutts, 1988; Croft et al., 2010) and training tasks (Yanci et al., 2014). However, HR was analyzed in absolute values instead of in relative values or according to the percentage of the time spent in each HR zone. Furthermore, none of these studies analyzed the differences between players with and without spinal cord injury (SCI). In addition, some studies cast doubt on the validity of HR measurements in athletes with SCI (Lewis et al., 2007; Jacobs et al., 1997), therefore, it could be interesting to analyze other ways of quantifying WB demands, such as rating of perceived exertion (RPE). RPE also forms a basis for prescribing an intensity of work paralleling that measured by physiological standards of HR, respiratory metabolic functions, and lactate production (Lewis et al., 2007). For this reason some authors (Ekblom & Goldbarg, 1971) proposed differentiated RPE in comparison to the overall measure, to better explain the mechanisms of the subjective perceived exertion that can determine physical work. They distinguished three rates of RPE, focussed on: 1) “local” or “muscle” (RPEmus, i.e. the feeling of strain in the working muscles), 2) “central” or “respiratory” (RPEres, i.e. perceived tachycardia, tachypnea, and even dyspnea) and 3) “overall” (RPE overall). Many studies involving persons with disability have studied the differentiated RPE method (Al-Rahamned et al., 2010; Goosey-Tolfrey et al., 2010b; Paulson et al., 2013) using laboratory environments but recently RPE (RPEres and RPEmus) has also been analyzed in WB matches (Iturricastillo et al., 2016a). Thus, it could be interesting to study the differentiated RPE method in intermittent high intensity training tasks such as SSG.

Therefore, the first aim of this study was to examine the physiological responses in commonly used basketball SSG (4 *vs.* 4) in well-experienced WB players with and without SCI. The second aim was to examine the development of the physiological variables during bouts and compare this evolution between groups.

5.3. Material and methods

Participants

Twelve Spanish First Division wheelchair basketball players (age 30.8 ± 9.5 years, sitting body height 82.9 ± 9.1 cm, body mass 75.7 ± 10.4 kg, HRmax 177.9 ± 13.7 beats·min^{-1}) participated in the study. The team was divided into two groups according to their injury type (Table 1). On the one hand, the group SCI (n = 6, sitting body height 82.1 ± 5.9 cm, body mass 72.4 ± 8.8 kg, HRmax 173.5 ± 15.3 beats·min^{-1}) and on the other hand, the group Non-SCI (n = 6, sitting body height 88.8 ± 2.0 cm, body mass 78.9 ± 11.5 kg, HRmax 182.3 ± 11.5 beats·min^{-1}). The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF) (from class 1 = players with low functional capacity to class 4.5 = players with high functional capacity). The inclusion criteria for the participants in the study were to have a valid license from the Spanish Federation of Sports for people with Physical Disabilities (FEDDF) and the certificate of disability that is necessary to belong to this federation. The Ethics Committee of the University of the Basque Country approved the study and all participants provided written informed consent as outlined in the Declaration of Helsinki (2013).

Procedures

This study was conducted over five consecutive weeks (from November to December) during the competitive period with the team training twice per week (Tuesday and Thursday) and competing at weekends. The SSG were part of the training sessions, so data were collected during the five consecutive Tuesdays, at the same time of the day (8–9 PM) and with at least 48 hours rest between sessions. All the players took part in at least 70% of the bouts during 5 consecutive weeks. Thus, a total of 144 individual observations met all requirements and were included in the analysis. Moreover, the analysis took into account all the players who had completed the full training task (4x4 minutes). These bouts were presented as bouts 1 to 4. No strenuous exercises were performed within the 48 h immediately prior to the training sessions and the researchers supervised the study at all times.

Data collection

Endurance test. In order to obtain the individual maximal heart rate (HRmax) of each player, all players completed a modified (10 m) Yo Yo intermittent recovery test level 1 (YYIR1 10 m) (Yanci et al., 2014; Granados et al., 2015) one week before the SSG were conducted. The YYIR1 10 m consist of repeated 2 × 10 m propels at a progressively increased speed controlled by audio bleeps from a pre-recorded source. This endurance test showed good reproducibility values (ICC = 0.83-0.94). All players were familiar with the field-testing procedures as they were part of their usual fitness assessment program. During the test, HR was continuously monitored at 1 s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). The HRmax was determined from the highest value from the YYIR1.

Small-sided games (SSG). The SSG were performed on a basketball pitch (15 x 28 m) with a duration (4 x 4 min separated by 2 min of passive recovery) which was strictly controlled and has already been implemented by other researchers (Yanci et al., 2014). The game rules were the same as in a competitive match, with the exception of no free throws after a fault or time-outs allowed during the 4 min periods to avoid excessive stops. During the SSG two supporting subjects were located out of the play area with several balls for immediate availability to minimize any disruption of play, and thus, the total duration of the SSG represented the effective time of exercise. The teams were balanced with respect to their disability and according to the IWBF functional classification. Thus, players with SCI were intermixed with players without SCI to balance both groups. All the SSG were preceded by a10 min standardized warm-up (3 min of aerobic activity without the ball plus two linear sprints and two sprints with a change of direction). Players were not allowed to consume any type of drinks during the recovery periods and all players received verbal encouragement from the coaches.

Table 1. Wheelchair basketball players' characteristics with (SCI) and without (Non-SCI) spinal cord injury.

PLAYER	GROUP	INJURY	AGE (years)	IWBF CLASSIFICATION	AIS GRADE	INJURY TIME (years)	TRAINING EXPERIENCE (years)
P1		Spina Bífida (L1)	16	1	A	16	2
P2		Spinal Cord Injury (T1-T2)	36	1	A	34	20
P3		Spinal Cord Injury (incomplete (C5-C6)	35	3	C	30	18
P4	SCI	Spinal Cord Injury (T10)	30	3	A	2	1
P5		Spinal Cord Injury (T12-L3)	42	1	A	18	7
P6		Spinal Cord Injury (T3)	19	1	A	12	2
Sample (n = 6)			30 ± 10	-	-	18.67 ± 11.78	8.33 ± 8.54
P7		Osteoarthritis congenital	40	4		40	21
P8		Hip labral tear	18	4		2	2
P9		Knee injury	25	4,5		5	2
P10		Viral Disease (polio)	35	3,5		33	4
P11	NON-SCI	Knee injury	41	4,5		9	9
P12		Amputation	35	4		28	15
Sample (n = 6)			32 ± 9	-		19.17 ± 15.82	8.83 ± 7.78

Results are in means ± SD; IWBF = International wheelchair basketball federation; AIS = ASIA Impairment Scale.

Heart Rate during SSG. HR was continuously monitored throughout the SSG at 1 s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Finland). The HRmean and HRpeak were recorded in absolute values for all bouts of the SSG. The HRmean expressed relative to each players' HRmax (%HRmax) for the entire 4 x 4 min SSG section of each training session was used for analysis (Sampaio et al., 2009). In addition, 4 HR zones were established, and the percentage of the time spent in each zone during SSG was calculated. The HR zones were defined as low (< 75% of HRmax), moderate (75–85% of HRmax), high (85–95% of HRmax), and maximal (> 95% of HRmax), according to previously established criteria in basketball (Ben Abdelkrim et al., 2007; Delextrat & Kraiem, 2013). The average value and standard deviation (SD) of each bout and group were used for the statistical analysis.

Tympanic temperature. A ThermoScan™5 IRT 4520 (Braun GmbH, Kronberg, Germany) was used to measure tympanic temperature. This is an infrared thermometer used in predictive mode that can provide a measurement in seconds using an algorithm that extrapolates from the speed at which temperature changes as the thermometer warms up (Yanci et al., 2014; Hamilton et al., 2013). The data were recorded before the warm-up and immediately at the end of each 4 min bout by the same investigator on all occasions. The average value and SD of each bout and group were used for the statistical analysis.

Perceived exertion. The 10-point scale proposed by Foster et al. (2001) was employed immediately after each SSG bout to determine how hard the exercise had been. Participants responded separately about the RPEres and the arm muscular RPEmus (Al-Rahamned et al., 2010; Granados et al., 2015; Paulson et al., 2013). The same investigator recorded the data on all occasions, immediately after each 4 min bout. Each player completed the RPE scale without the presence of other players and they could not see the values of other participants. Players were educated about the 10-point scale during a month before the data collection. Moreover, this scale was used in all the previous training sessions. The average value and SD of each bout and group were used for the statistical analysis.

Data analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used for the calculation of the mean and standard deviations. Data were screened for normality of distribution and homogeneity of variances using a Shapiro-Wilk normality test. Student's-t test for independent samples was used to determine the differences between groups in physiological responses in each bout independently, and ANOVA repeated measures with an appropriate Bonferroni post-hoc test was used to compare results among bouts in each group (SCI and Non-SCI) independently. Also, the between-groups comparison from baseline to different bouts was calculated with a two way mixed ANOVA (bout x group). The $p < 0.05$ criterion was used to establish statistical significance.

5.4. Results

The absolute mean values of the physiological responses (HRmean, HRpeak and tympanic temperature) in a 4 *vs.* 4 SSG are presented in Table 2. The Non-SCI group showed significantly higher values than the SCI group in HRmean and HRpeak, but not in tympanic temperature. In addition, significant differences were observed between the first and the other bouts in HRmean and HRpeak in the Non-SCI group, but not in the SCI group. Regarding tympanic temperature, the final bouts showed differences with respect to the first bouts, in both groups. According to the two way ANOVA analysis (bout x group), no variable showed statistical significance.

In relation to HRmean and HRpeak relative values (%HRmax), non-significant differences were observed between both groups (SCI vs. Non-SCI), in all bouts. However, significant differences were observed in the Non-SCI group among bouts in HRmean (Figure 1A) and HRpeak (Figure 1B), but not in the SCI group.

Similarly, when intensity of exercise was expressed as a percentage of the time spent in different HR zones of HRmax, non-significant differences were observed between the SCI and Non-SCI groups (Table 3). With respect to the differences among bouts in the Non-SCI group, the percentage of the time spent at 75–85% was significantly lower in the third and fourth bouts compared to the first one. In addition, significantly higher values were observed in the Non-SCI group in the second and third bouts compared to the first in the percentage of time spent at more than 95% of HRmax.

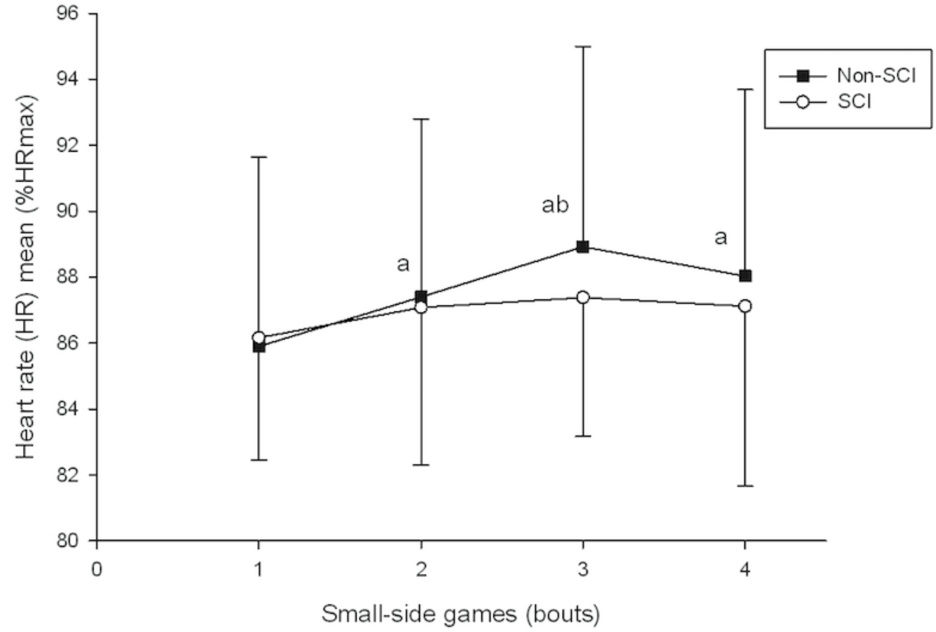
The SCI group showed significantly higher values in RPEres in the last bout but no significant differences were shown in RPEmus (Figure 2). Moreover, for the Non-SCI group in RPEres (Figure 2A), there were significantly higher values in the third and fourth bouts compared to the first one. Regarding RPEmus (Figure 2B) significantly higher values were observed in all bouts compared to the first one and in the third and fourth bouts compared to the second one for both groups. In relation to the SCI group, there were significant differences in all bouts compared to the first one.

Table 2. Physiological responses between players with (SCI) and without (Non-SCI) spinal cord injury in WB 4 *vs.* 4 small-sided games.

	HR mean (beats · min^{-1})		HR peak (beats · min^{-1})		Tympanic Temperature (Celsius)	
	SCI	**Non-SCI**	**SCI**	**Non-SCI**	**SCI**	**Non-SCI**
Bout 1	148.67 ± 14.85	157.4 ± 9.4	161.14 ± 14.5*	170.9 ± 8.03	36.87 ± 0.51	36.75 ± 0.71
Bout 2	150.17 ± 14.86*	160.1 ± 8.37^{a}	163.1 ± 15.75*	173.35 ± 8.29^{a}	36.89 ± 0.63	36.77 ± 0.74
Bout 3	150.5 ± 11.93**	162.85 ± 9.25^{ab}	161.5 ± 13.38**	176.35 ± 8.76^{a}	36.83 ± 0.68	36.9 ± 0.63
Bout 4	150.1 ± 13.86**	161.2 ± 7.9^{a}	161.83 ± 13.53**	174.95 ± 7.27^{a}	36.96 ± 0.66^{a}	36.98 ± 0.54^{ab}
Average	149.85 ± 13.49***	160.39 ± 8.95	161.85 ± 13.88***	173.89 ± 8.2	36.89 ± 0.61	36.85 ± 0.66

*Values are means (± SD), WB = wheelchair basketball, HR = heart rate. *p < 0.05, **p < 0.01, ***p < 0.001: significant difference between SCI and Non-SCI players. ^{a} significant difference (p < 0.05) compared to bout 1, ^{b} significant difference (P < 0.05) compared to bout 2.*

1A)



1B)

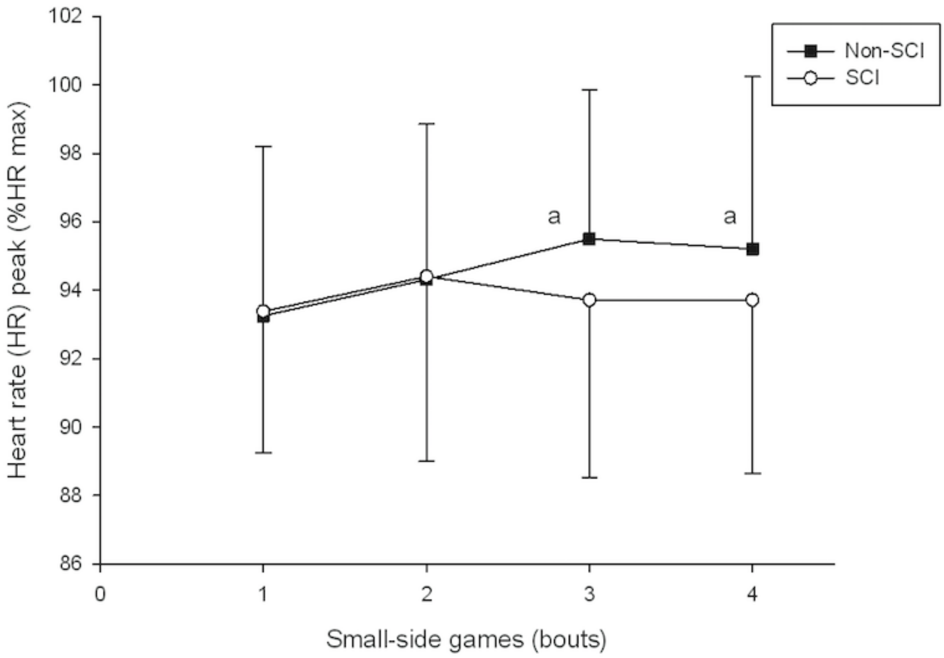


Figure 1. *Relative values (%HRmax) bout to bout for players with spinal cord injury (SCI) and without spinal cord injury (Non-SCI) in HRmean (1A) and HRpeak (1B). HR = heart rate, [a]Significant differences ($p < 0.05$) compared to bout 1, [b]Significant differences ($p < 0.05$) compared to bout 2.*

Table 3. The percentage of the time spent in different heart rate (HR) zones between players with (SCI) and without (Non-SCI) spinal cord injury in wheelchair basketball 4 *vs.* 4 small-sided games.

HR zones (%HRmax)	Group	Bout 1	Bout 2	Bout 3	Bout 4
Time at <75%	SCI	7.77 ± 7.83	4.3 ± 3.56	3.85 ± 4.23	4.86 ± 7.14
	Non-SCI	8.3 ± 8.54	6.72 ± 6.24	7.91 ± 10.1	7.87 ± 12.17
Time at 75 - 85%	SCI	29.82 ± 27.08	35.89 ± 29.54	28.98 ± 26.05	27.32 ± 26.22
	Non-SCI	35.95 ± 28.13	27.64 ± 25.5	20.18 ± 16.89[a]	24.08 ± 19.23[a]
Time at 85 - 95%	SCI	53.33 ± 25.13	44.02 ± 24.29	53.15 ± 23.98	50.03 ± 27.22
	Non-SCI	38.62 ± 21.24	43.97 ± 23.04	45.43 ± 25.19	44.9 ± 23.92
Time at >95%	SCI	9.65 ± 16.35	15.83 ± 24.63	14.06 ± 20.22	17.74 ± 24.45
	Non-SCI	15.74 ± 25.25	21.25 ± 31.60[a]	26.38 ± 32.83[a]	23.1 ± 27.02

Values are means (± SD), [a] significant difference ($p < 0.05$) compared to bout 1.

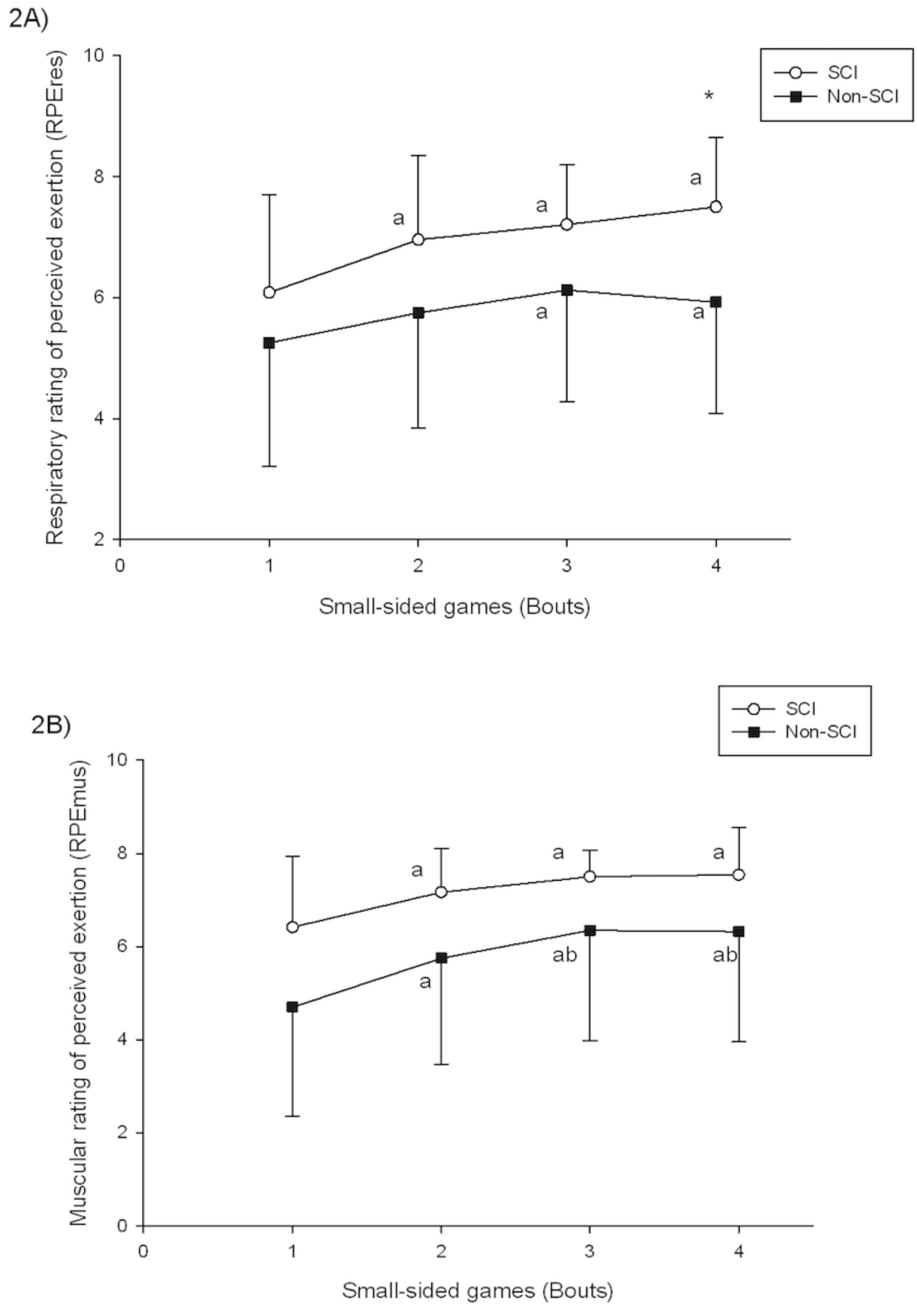


Figure 2. *Respiratory (2A) and muscular (2B) perceived exertion bout to bout for players with spinal cord injury (SCI) and without spinal cord injury (Non-SCI).*

**Significant differences ($P < 0.05$) between SCI and Non-SCI.*

[a]Significant differences ($p < 0.05$) compared to bout 1, [b]Significant differences ($p < 0.05$) compared to bout 2.

5.5. Discussion

In this study we examined the HR responses, tympanic temperature and perceived exertion in 4 *vs.* 4 SSG. Our results show that the players with SCI and without SCI may have similar HR relative values (%HRmean, %HRpeak, percentage of the time spent in different HR zones), although the Non-SCI group attained higher absolute HR (HRmean and HRpeak) values. Furthermore, no differences were observed between the two groups in relation to tympanic temperature. However, the players with SCI reported significantly higher values in RPEres in the last bout than the Non-SCI group for the same SSG.

Several studies have investigated the use of HR in able bodied players as an indicator of exercise intensity (Ben Abdelkrim et al., 2007; Delextrat & Kraiem, 2013; Sampaio et al., 2009), however, there are few works in reference to wheelchair sports. Croft et al. (2010) showed an average HRmean of 146 ± 16 beats·min^{-1} in wheelchair tennis and 163 ± 11 beats·min^{-1} in WB players during a match. Generally, our results are lower than those observed by Croft et al. (2010), but almost the same or higher than those reported by others in the literature (range 128 – 151 beats·min^{-1}, respectively) (Bloxham et al., 2001; Coutts, 1988; Schmid et al., 1998) for both groups (SCI and Non-SCI). The players with SCI attained a significantly lower HRmean (149.85 ± 13.49 beats·min^{-1} *vs.* 160.39 ± 8.95 beats·min^{-1}) and HRpeak (161.85 ± 13.88 beats·min^{-1} *vs.* 173.89 ± 8.2 beats·min^{-1}) than the Non-SCI group. Nevertheless, the SD of HRmean and HRmax were higher than those observed in Non-SCI group. In the case of SCI group, the results were higher than those reported by Goosey-Tolfrey & Leicht (2013) probably due to the diversity in the lesion level of the SCI group of our study. It is well known that the work capacity of individuals with SCI is limited by loss of functional muscle mass and sympathetic control. Sympathetic nervous system impairment limits control of regional blood flow and cardiac output, and HRmax following cervical lesions may be reduced to 110 to 130 beats·min^{-1} (Goosey-Tolfrey & Leicht, 2013). So that, this suggests that absolute HR values have to be interpreted with caution in players with SCI during high intensity training tasks as they can lead to error.

Some authors reported absolute HR values in relation to a competitive WB match (Bloxham et al., 2001; Coutts, 1988; Schmid et al., 1998) but only one study reported relative HRmean values (83.9 ± 1.9%) (Croft et al., 2010). In this sense, both groups (SCI and Non-SCI) reached similar relative HRmean values (% HRmax) to those reported by Croft et al. (2010) during WB matches (SCI = 86.16 ± 3.7%; Non-SCI = 85.9 ± 5.73%). So, to improve physical capacities, SSG could be useful because they represent highly intense games that simulate real play situations. Despite significant differences being observed in absolute values of HRmean and HRpeak between players with and without SCI during the 4 *vs.* 4 SSG, there were none in the relative values (%HRmean, %HRpeak, percentage of the time spent in different HR zones) However, the SSG might be good training tasks for WB players due to the similarities with the physiological responses involved in a match. This could be an interesting finding as both groups may train at the same relative intensity, in spite of the difficulty of players with SCI to reach the HRmax. This means that when the values are expressed in relative values of their HRmax, the differences in the physiological demands of SSG for players with and without SCI disappeared. For this reason, relative HR could have more applicability for coaches or physical trainers to quantify the training load instead of absolute HR values.

The training for physiological responses during matches have been analyzed by objective (means of HR) and subjective (RPE) methods (Iturricastillo et al., 2016a; Yanci et al., 2014). However, there is controversy in the literature about the relationship of HR and RPE for people with SCI (Lewis et al., 2007; Jacobs et al., 1997; Paulson et al., 2013). Jacobs et al. (1997) found a strong linear association between HR and VO_2 in participants with paraplegia, but not between HR and RPE during functional neuromuscular stimulation assisted ambulation. The results are consistent with those of Lewis et al. (2007) who concluded that RPE is an invalid indicator of exercise intensity in participants with paraplegia. In contrast, evidence suggests that the RPE is effective in controlling moderate (50% VO_2peak) and vigorous (70% VO_2peak) intensities during hand cycling exercise in participants with SCI (Paulson et al., 2013). Considering that most studies were done in a laboratory setting at a given intensity or in incremental tests instead of field-testing, it would be interesting to assess the HR-RPE relationship during the game itself (Coutts, 1988) and specific training tasks. The most intriguing findings of the study were the contrasting tendencies of RPEres values with respect to relative HR values in players with SCI, thus, supporting the controversy. However, for the Non-SCI group there was a similar tendency in HR and RPE, as they showed a similar rising trend in RPE values when increasing absolute and relative HR during bouts. In this sense, the intermittent high intensity nature and characteristics of the SSG, as well as physiological impairments or diverse functional ability could be the reason for the contrasting tendencies between HR and RPE values. More studies are therefore necessary to analyse the objective and subjective values in players with SCI during high intensity intermittent training tasks because both methods might be measuring a different internal load during SSG.

It is well accepted that people with SCI have a lesser ability to regulate core temperature due to impaired vasomotor and sudomotor activity below their level of injury (Trbovich et al., 2014). In this case, non-significant differences were observed between the SCI and Non-SCI groups in 4 *vs.* 4 full court SSG, regarding tympanic temperature. This might be due to the short duration of the exercise, despite it being at high intensity. Nevertheless, in both groups significantly higher values were observed between the first and the last bout. Furthermore, the Non-SCI group showed significantly higher values in the last bout with respect to the second bout. Core temperature plays an important role in physical performance (West et al., 2014), given that it could be adversely affected by the increase in core temperature at rest and during exercise (Bhambani, 2002). If adequate fluid intake is not maintained, the players' thermoregulatory capacity is diminished (Jung et al., 2005). In individuals with SCI, this situation may become a potential physiological problem, since a lack of sympathetic vasomotor adjustment and reduced sweating capacity below the lesion level may hamper appropriate blood redistribution and limit cooling efficiency (Theisen & Vanlandewijck, 2002).

5.6. Conclusions

The main conclusion of this study is that players with and without SCI may have similar HR relative values, although the Non-SCI group attained higher absolute HR values. So that, it would be interesting to analyze not only the absolute values of HR but the relative values during wheelchair basketball to quantify the intensity and the internal load of SCI players. For future studies, it would be interesting to compare the relative HR values between SCI and Non-SCI players in different training tasks or matches to determine if the training or match intensity is the same for every player or not. On the other hand, the players with SCI reported significantly higher values in respiratory RPE in the last bout than the Non-SCI group for the same SSG. Thus, by means of SSG we might be able to develop anaerobic capacity in a similar manner both in the Non-SCI group and the SCI group. However, the contrasting tendencies between HR and RPE values lead us to reflect about the need for more studies in players with SCI as both methods (HR and RPE) might be measuring a different internal load during SSG.

6. SEIGARREN KAPITULUA

Quantifying wheelchair basketball match load: a comparison of heart rate and perceived exertion methods

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6.1. Abstract

Purpose: The aim of this study was to describe the objective and subjective match load (ML) of wheelchair basketball (WB) and to determine the relationship between session heart rate-based ML (HR-based ML) and perceived exertion-based ML (RPE-based ML) methods. **Methods:** HR-based measurements of ML included Edward's ML and Stagno training impulses ($TRIMP_{MOD}$) whilst RPE-based ML measurements included respiratory (sRPEres ML) and muscular (sRPEmus ML). Data were collected from ten WB players during a whole competitive season. **Results:** Edward's ML and $TRIMP_{MOD}$ averaged across 16 matches were 255.3 ± 66.3 and 167.9 ± 67.1 AU respectively. In contrast, sRPEres ML and sRPEmus ML were found to be higher (521.9 ± 188.7 and 536.9 ± 185.8 AU respectively). Moderate correlations (r = 0.629 – 0.648, $p < 0.001$) between Edward's ML and RPE-based ML methods were found. Moreover, similar significant correlations were also shown between the $TRIMP_{MOD}$ and RPE-based ML methods (r = 0.627 – 0.668, $p < 0.001$). That said, only ≥40% of variance in HR-based ML was explained by RPE-based ML which could be explained by the heterogeneity of physical impairment type. **Conclusion:** results suggest that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players.

Key words: *match activity, RPE, TRIMP, training load, Paralympic.*

6.2. Introduction

To evaluate the success of training, coaches need to systematically monitor athletes' internal training load (TL) (Alexandre et al., 2012). Understanding TL's will allow coaches to monitor the effectiveness of training and competitive stimuli in provision of a successive training plan (Lupo et al., 2014). Consequently, TL has been analyzed in many able-bodied team sports during training (Campos-Vazquez et al., 2015; Fanchini et al., 2015; Lupo et al., 2014; Manzi et al., 2010; Scanlan et al., 2014) and competitive match play (Bridge et al., 2009; Costa et al., 2013; Rebelo et al., 2012). Monitoring TL or match load (ML) helps the coach individualize training with respect to simulating game play via certain drills in training or indeed individualizing the physical load due to the player's positional requirements. Thus, methods based on the analysis of heart rate (HR) as the measurement of Banister's training impulses (Banister, 1991), Edward's method (Edwards, 1993) or modified Stagno's $TRIMP_{MOD}$ (Stagno et al., 2007) have been used to quantify TL in many sports such as soccer (Alexiou et al., 2008; Campos-Vazquez et al., 2015; Impellizzeri et al., 2004; Los Arcos et al., 2014b; Rebelo et al., 2012), Australian football (Moreira et al., 2015; Scott et al., 2013) and water-polo (Lupo et al., 2014).

Evidently, not only the analysis of HR have been used to quantify TL, since over the last decade researchers are combining other objective measures of TL such as athlete's perceived exertion (RPE). For example, several authors have successfully verified the quantification of TL or ML by multiplying an athlete's RPE for the total duration (min) of the training or match play in team sports (Foster et al., 2001; Impellizzeri et al., 2004; Lupo et al., 2014; Manzi et al., 2010; Scott et al., 2013). Extending this further, recent work has differentiated between the subjective measure of RPE and noted RPE as scores relating to 'overall' or 'respiratory' RPE (RPEres) and 'muscular' RPE (RPEmus) (Los Arcos et al., 2014b; Weston et al., 2015). This may be pertinent when working in adaptive sports such as wheelchair basketball (WB) since wheelchair propulsion involves exercise of the upper extremities which are prone to peripheral fatigue (Lenton et al., 2008).

With the increasing professionalism of Paralympic Sport, it is surprising to see that little is known about the competitive conditions that are faced by the wheelchair sportsperson (Croft et al., 2010; Gómez et al., 2014; Rhodes et al., 2015; Roy et al., 2006; Sindall et al., 2013). There is a paucity of data that quantifies the physiological responses during WB game play (Bloxham et al., 2001; Coutts, 1988; Croft et al., 2010; Schmid et al., 2013) or mobility performance via tracking distances covered, like those reported in the wheelchair sports of tennis and rugby (Rhodes et al., 2015; Sindall et al., 2013). To our knowledge there are no studies examining the HR-based method in quantifying TL in wheelchair sports despite our anecdotal observations that many coaches have access to these methods (e.g., HR monitors). An alternative low cost and practical strategy to quantify ML is session-RPE (Foster et al., 2001), which has been extensively shown as a valid and reliable load-monitoring tool in many able-bodied team sports (Impellizzeri et al., 2004; Foster et al., 2001) Moreover, monitoring internal loads using session-

RPE and hormonal responses has been identified in simulations and official basketball competitive outputs (Moreira et al., 2012), but yet to be proven a viable option to consider within wheelchair sports. Because the disability type influences the heart rate response to wheelchair sport (Barfield et al., 2005) may be necessary to meet ML by HR-based method and RPE-based methods specifically in WB players.

Therefore, the purpose of this study was to describe the objective and subjective ML of WB game play and to investigate the relationship between HR-based ML and RPE-based ML methods across a competitive WB season.

6.3. Material and methods

Participants

Ten Spanish First Division male WB players (age 34 ± 8 years, time since injury 24 ± 12 years, WB training experience 11 ± 7 years and 4-6 training hours per week) volunteered to participate in the study. The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF) (Table 1). This study was approved by the institutional research ethics committee and all participants provided written informed as outlined in the Declaration of Helsinki (2013).

Data Collection Period

Data were collected over a 6 month competitive season during the squad's build up to end of season game play in March. During this period players undertook two training sessions and one match per week. Data from 16 matches were collected from the competitive match play as HR-based ML and RPE-based ML. At least all players completed 4 matches and in this sense, a minimum of 4 full observations was considered for the analysis. Thus, a total of 111 individual observations met all requirements and were included in the analysis.

Endurance test

In order to obtain individual maximal heart rates (HRmax), a 10m Yo-Yo intermittent recovery test level 1 (YYIR1) as described by Yanci et al. (2015) were completed by all players one week before the competition period. This endurance test has been verified using WB players and has shown good reproducibility (ICC = 0.83-0.94). Importantly, all players were familiar with this test as it had been part of their usual fitness assessment program. During the test, HR was continuously monitored at 1s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). The maximum HR was determined from the highest value from either the YYIR1 or game play.

Determination of match load (ML)

The ML for each player was determined during each match by four different methods; Edward's ML (Edwards, 1993) and $TRIMP_{MOD}$ (Stagno et al., 2007), and other two RPE-based methods described later were used in order to quantify ML. The HR was continuously monitored throughout the matches at 1s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). For ease of data collection, the whole match time (the rest time and substitution time on the bench) was reported for the analysis. Collection was only paused during any periods of extended stoppages (time-outs, equipment calls) throughout the match since WB players also remain active during the stopped game clock.

Edwards' ML method. Match load calculation was performed as proposed by Edwards (Edwards, 1993), in brief this included the total volume of match intensity which considers 5 zones of different intensity. The calculation was performed for each session by multiplying the accumulated duration each HR zone (min) for a value assigned to each intensity zone (90-100% HRmax = 5, 80-90% HRmax = 4, 70-80% HRmax = 3, 60-70% HRmax = 2, 50-60% HRmax = 1), and finally summarizing the results (Manzi et al., 2010; Scanlan et al., 2014).

$TRIMP_{MOD}$ method. Calculations of TRIMP were also performed as described by Stagno et al. (2007). For this calculation, the ML is determined by calculating the result of multiplying the match duration (min) at each of the current zones for the weighting factor for each zone (93-100% HRmax = 5.16; 86-92% HRmax = 3.61; 79-85% HRmax = 2.54; 72-78% HRmax = 1.71; 65-71% HRmax = 1.25), and performs the summation of the results (Campos-Vazquez et al., 2015; Stagno et al., 2007).

Rating of Perceived Effort (RPE) based methods. RPE using the 0-10 point scale (Foster et al., 2001) was recalled by each player at the end of each match. Participants differentiated between the overall or respiratory RPE (RPEres) and the arm muscle RPE (RPEmus) as previously noted for wheelchair ambulation (Lenton et al., 2008; Paulson et al., 2013). In accordance to the work of Foster et al. (2001) to estimate the RPE-derived ML (sRPEres ML and sRPEmus ML), the RPEres and RPEmus values were multiplied by the total duration of the match (min). Players were fully familiarized with the 0-10 point scale before the data collection since these methods had been used previously during the pre-season.

Data analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used for the calculation of the mean and standard deviations (SD). Data were screened for normality of distribution. The relationships between HR-based ML methods and RPE-based ML scores were assessed using Pearson's product moment correlation (r), as well as the coefficient of determination (R^2). The $p < 0.05$ criterion was used for establishing statistical significance.

6.4. Results

As shown in Table 1, game play elicited greater mean HRmax values than that found in the YYIR1 (188 ± 13 vs. 178 ± 12 beat·min^{-1} respectively, $p < 0.001$) and so thereafter these HR values obtained from game play were used for the following calculations.

The ML of each match across the 16 matches is shown in the Figure 1. The mean value utilizing the methods of Edward's ML was 255.3 ± 66.3 AU and for $TRIMP_{MOD}$ was 167.9 ± 67.1 AU. Moreover, the means for subjective ML were 521.9 ± 188.7 AU and 536.9 ± 185.8 AU, sRPEres and sRPEmus, respectively.

Table 1. Wheelchair basketball players' characteristics.

Player	Physical Impairment	IWBF Classification	Age (years)	Injury time (years)	Training experience (years)	Modified YYIR1 (beat·min^{-1})	Match (beat·min^{-1})
1	Spinal Cord Injury (T12-L3)	1	42	18	7	191	196
2	Spina Bífida (L1)	1	16	16	2	180	195
3	Spinal Cord Injury (T1-T2)	1	36	34	20	154	160
4	Viral Disease (polio)	2	35	33	4	198	204
5	Spinal Cord Injury (incomplete C5-C6)	3	35	30	18	169	182
6	Viral Disease (polio)	3.5	33	31	14	176	189
7	Osteoarthritis congenital	4	40	40	21	179	183
8	Double amputation below knee	4	35	28	15	185	201
9	Knee injury	4.5	41	9	9	169	187
10	Knee injury	4.5	25	5	2	182	184
Sample (n = 10)		-	34 ± 8	24 ± 12	11 ± 7	178 ± 12	188 ± 13

YYIR1 = Yo-Yo intermittent recovery level 1 test; IWBF = International wheelchair basketball federation.

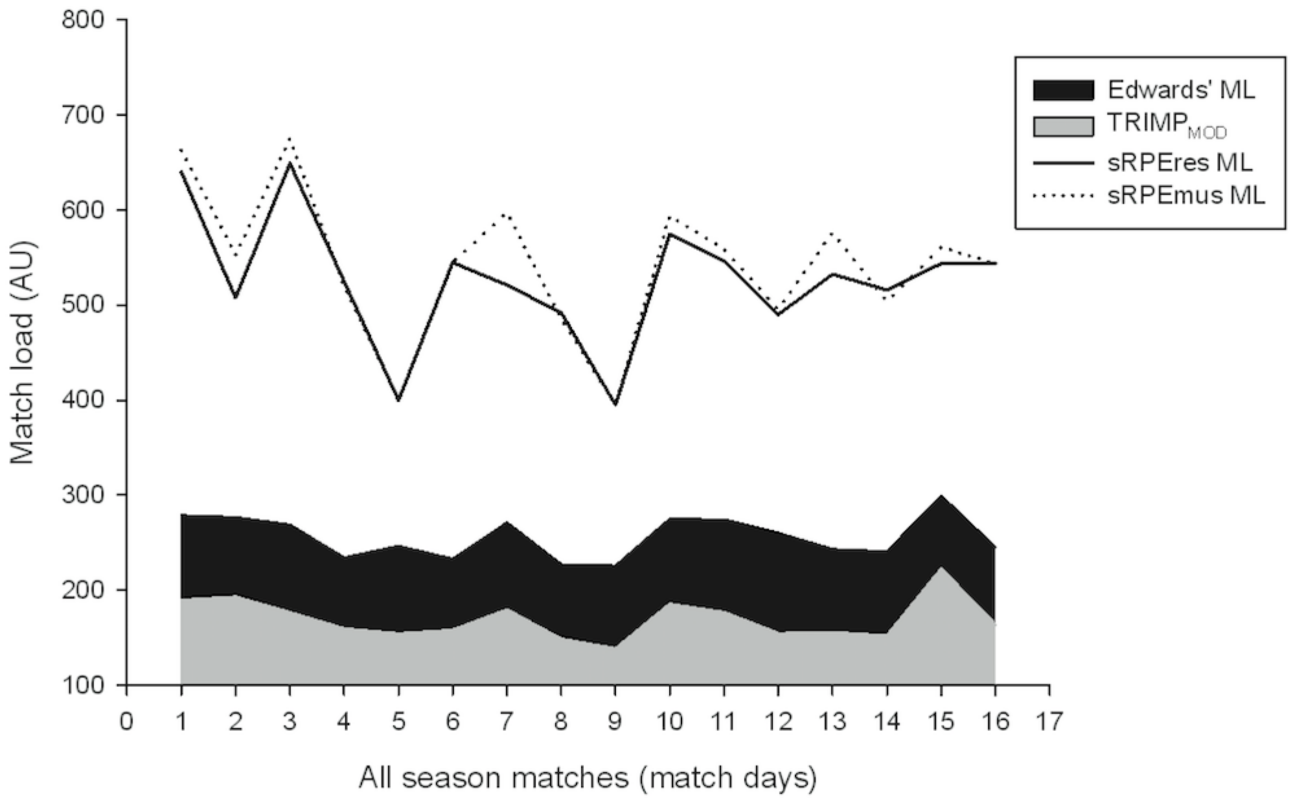

***Figure 1.** Edward's match load (Edward's ML), Stagnos' modified TRIMP (TRIMP$_{MOD}$) and respiratory and muscular rating of perceived exertion based match load (sRPEres ML and sRPEmus ML) for the whole team during the 16 wheelchair basketball matches.*

AU = arbitrary units; Edward's ML = Edward's match load; TRIMP$_{MOD}$ = Stagnos' modified training impulse; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load.

According to the whole team values, moderate correlations were found between RPE-based ML methods and Edwards's ML (sRPEres ML, r = 0.629, R^2 = 0.40, p < 0.001 and sRPEmus ML, r = 0.648, R^2 = 0.42, p < 0.001) and TRIMP$_{MOD}$ (sRPEres ML, r = 0.627, R^2 = 0.39, p < 0.001 and sRPEmus ML, r = 0.668, R^2 = 0.45, p < 0.001) methods (Figure 2). Nevertheless, there were not significant correlations in all individuals between HR-based ML and RPE-based ML methods (Table 2).

Table 2. Individual correlations between HR-based ML (Edward's ML and $TRIMP_{MOD}$) and RPE-based ML (sRPEres ML and sRPEmus ML).

	Edward's ML						**$TRIMP_{MOD}$**					
	sRPEres ML			**sRPEmus ML**			**sRPEres ML**			**sRPEmus ML**		
Player	***r***	**CI (95%)**	**R^2**	***r***	**CI (95%)**	**R^2**	***r***	**CI (95%)**	**R^2**	***r***	**CI (95%)**	**R^2**
1	0.63*	0.15-1.12	0.40	0.69**	0.24-1.15	0.48	0.66*	0.18-0.13	0.43	0.69**	0.23-1.15	0.47
2	0.65**	0.20-1.11	0.43	0.59*	0.11-1.08	0.35	0.78**	0.40-1.15	0.60	0.70**	0.27-1.13	0.49
3	0.48	-0.40-1.36	0.23	0.69	-0.03-1.41	0.48	0.36	-0.57-1.30	0.13	0.66	-0.09-1.41	0.43
4	0.92	-0.24-2.09	0.85	0.92	-0.24-2.09	0.85	0.98*	0.31-1.64	0.95	0.98*	0.31-1.64	0.95
5	0.71**	0.21-1.21	0.50	0.72**	0.22-1.21	0.51	0.68*	0.14-1.24	0.47	0.68*	0.13-1.24	0.46
6	0.47	-0.15-1.09	0.22	0.41	-0.23-1.05	0.17	0.61*	0.05-1.17	0.37	0.55	-0.04-1.14	0.30
7	0.62*	0.02-1.04	0.38	0.67*	0.01-1.03	0.45	0.67*	0.01-1.03	0.44	0.64*	0.10-1.07	0.41
8	0.71**	0.26-1.15	0.50	0.52	-0.01-1.06	0.27	0.61*	0.11-1.11	0.37	0.46	-0.09-1.02	0.22
9	0.53*	0.06-1.17	0.28	0.52*	0.15-1.19	0.28	0.52*	0.14-1.19	0.27	0.59*	0.10-1.18	0.35
10	0.89*	0.07-1.72	0.80	0.85	-0.13-1.83	0.72	0.85	-0.13-1.82	0.72	0.82	-0.25-1.88	0.67
Min	0.47	-	0.22	0.41	-	0.17	0.36	-	0.13	0.46	-	0.22
Max	0.92	-	0.85	0.92	-	0.85	0.98	-	0.95	0.98	-	0.95
Mean	0.66 ± 0.16		0.46 ± 0.22	0.66 ± 0.15		0.46 ± 0.21	0.67 ± 0.17		0.48 ± 0.23	0.68 ± 0.14		0.48 ± 0.21

*r = coefficient; CI = 95% confidence interval; R^2 = coefficient of determination; Min = minimum value; Max = maximum value; HR-based ML = heart rate based match load; Edward's ML = Edward's match load; $TRIMP_{MOD}$ = Stagnos' modified training impulse; sRPE ML = session rating of perceived exertion match load; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load; *p < 0.05 and **p < 0.01: significant correlations between RPE-based TL and HR-based TL methods.*

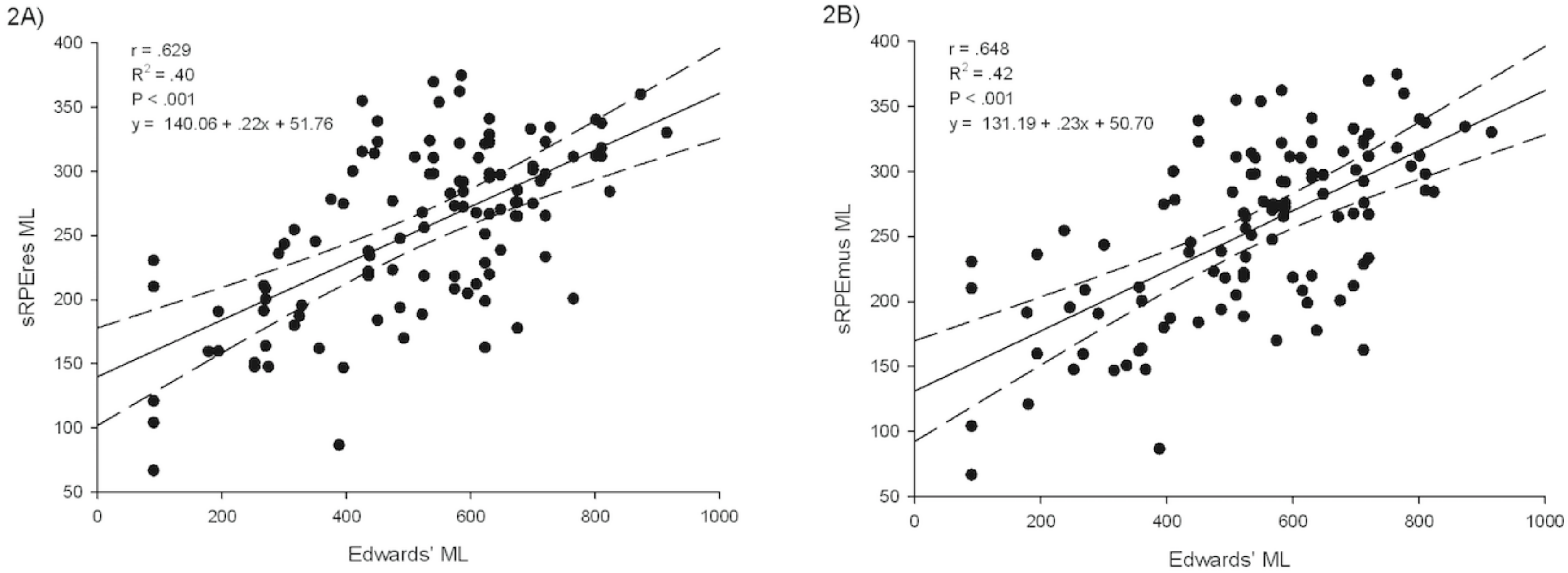

Figure 2. *Correlation between overall HR-based ML (Edward's ML and $TRIMP_{MOD}$) and sRPE-based match load (sRPEres ML and sRPEmus ML) of 111 observations. Confidence interval (CI) 90%.*

HR-based ML = heart rate based match load; Edward's ML = Edward's match load; $TRIMP_{MOD}$ = Stagnos' modified training impulse; sRPE ML = session rating of perceived exertion match load; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load.

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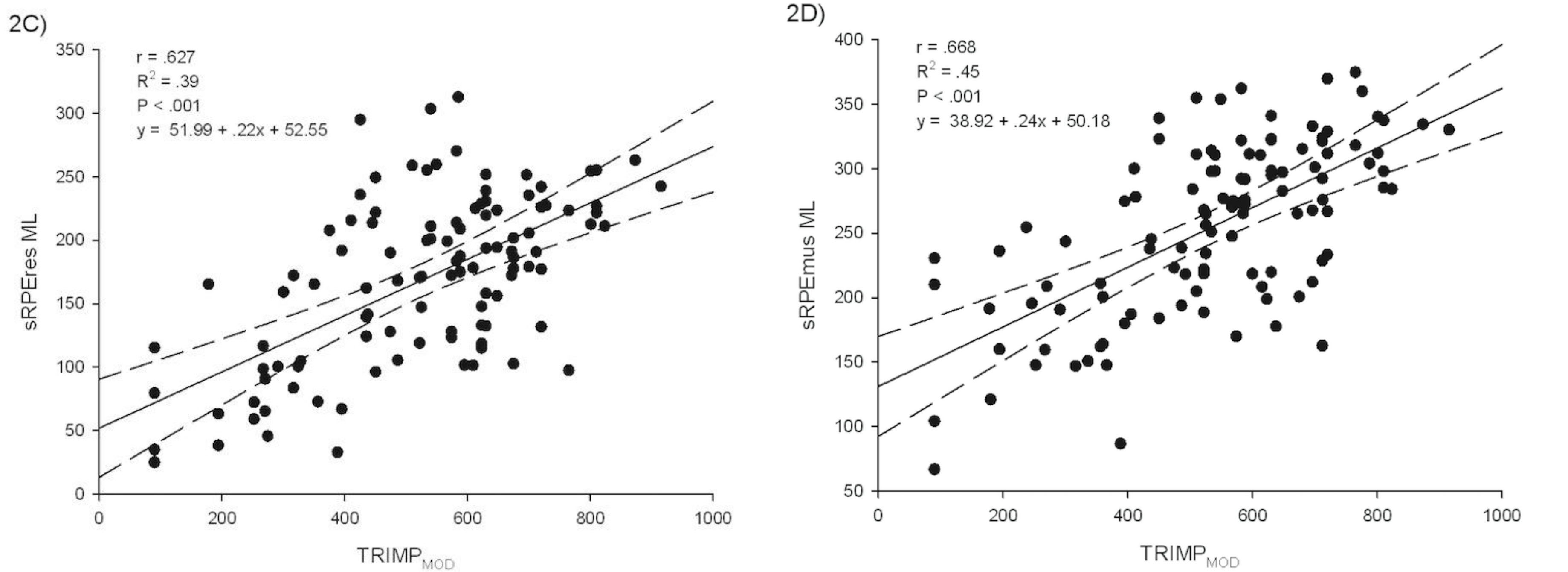

Figure 2. *Correlation between overall HR-based ML (Edward's ML and $TRIMP_{MOD}$) and sRPE-based match load (sRPEres ML and sRPEmus ML) of 111 observations. Confidence interval (CI) 90%.*

HR-based ML = heart rate based match load; Edward's ML = Edward's match load; $TRIMP_{MOD}$ = Stagnos' modified training impulse; sRPE ML = session rating of perceived exertion match load; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load

The correlations between objective and subjective methods with the mean values of each match were moderate (r = 0.511 – 0.609; R^2 = 0.261 – 0.371; $p < 0.05$). As was expected high correlations were observed between Edward's ML and $TRIMP_{MOD}$ methods (r = 0.959; R^2 = 0.920; $p < 0.001$) and sRPEres ML and sRPEmus ML methods (r = 0.919; R^2 = 0.842; $p < 0.001$).

6.5. Discussion

The RPE-based TL method has been widely correlated with stress responses (Moreira et al., 2012) and the HR-based TL score in many able-bodied sports (Borresen et al., 2008; Foster et al., 2001; Impellizzeri et al., 2004; Lupo et al., 2014). However, to date it is unknown how transferable these methods are to the sport of WB that involves wheelchair propulsion of persons with a physical impairment. Thus, the current study described the ML and investigated the HR-based ML and RPE-based ML methods in WB players during a whole competitive basketball season. The results revealed that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players with some cautionary attention due to RPE-based ML should not be seen as a substitute of HR-based ML. With accordance to the individual correlations between subjective and objective methods there were not a significant relation in all the players, thus, both the large heterogeneity of physical impairment types and a reduced number of cases for each individual could condition the relation between both methods.

The current study found that when using the HR-based methods adopted by Edward's that the ML values were higher than utilizing the $TRIMP_{MOD}$ (255.3 ± 66.3 AU vs. 167.9 ± 67.1 AU). That said, both these values were found to be lower than those reported for non-disabled basketball practices and/or games (652 ± 59 AU, Edward's ML) (Foster et al., 2001). Moreover, whilst using the subjective methods for quantifying ML was found to be similar between methods for the WB players (521.9 ± 188.7 AU vs. 536.9 ± 185.8 AU; sRPEres for sRPEmus, respectively). Similar to above, Foster et al. (2001) found higher sRPE values (744 ± 84 AU) during basketball games. Obviously, this comparison must be done with caution since a complete spinal cord injury (SCI) results in paralysis of the voluntary muscles below the level of lesión (Price, 2010). Consequently, a reduced muscle mass is available for exercise. In conjunction with factors such as reduced sympathetic nervous system innervation and cardiovascular function, maximal exercise capacity is reduced when compared with able-bodied individuals (Price, 2010). The difference between our findings and those reported by Foster et al. (2001) were 29.9% for sPREres and 27.8% for sRPEmus in AU units. These lower values could be due to the muscle mass differences between modalities and for the different consequences of a SCI as previously mentioned.

The relationship between objective and subjective methods has been widely analyzed in training tasks (Manzi et al., 2010; Scanlan et al., 2014) and competition (Costa et al., 2013;

Rebelo et al., 2012) in team sports. In our study, the relationship between RPE-based ML and HR-based ML methods was moderate (r = 0.627 for sRPEres ML and r = 0.668 for sRPEmus ML). Such findings are consistent with previous studies involving other team sports (Costa et al., 2013; Rebelo et al., 2012). In the same way, very high correlations were found between sRPEres ML and sRPEmus ML (r = 0.919). The relationship between HR-based ML and RPE-based ML in the studies previously referred above were moderate between objective and subjective methods (r range = 0.60 - 0.61; $p < 0.05$) in soccer players and soccer referees (Costa et al., 2013; Rebelo et al., 2012). As Imperizelli et al. (2004), we suggest that the RPE-based ML score cannot yet replace the HR-based ML methods as a valid measure of exercise intensity, as sRPEres ML and sRPEmus ML could only explain 40% of the variation measured by HR, or even less in some cases. This could be due to the intermittent exercise nature of team sports (aerobic and anaerobic sources) reducing the grade of correlations between RPE-based TL and Edward's HR-based TL method. In addition, Bridge et al. (2009) have reported that under certain training and competitive conditions, athletes tend to report lower RPE-based TL than their actual HR responses. Other authors, such as Lupo et al. (2014) inferred that the game may tend to make less reliable the RPE values because of a high grade of involvement and good time during the practice, therefore, underestimating their efforts. For this reason, Borresen et al. (2008) attempted to identify characteristics that may explain the variance not accounted for in the relationship between the objective (HR-based TL) and subjective (RPE-based TL) methods of quantifying training load. Rhodes et al. (2015) clearly showed the intermittent nature of match play during wheelchair rugby which is a similar wheelchair sport to that of WB. Of interest were the noted differences in high intensity activities among the functional classification during a wheelchair rugby match. This could be attributed to the superior trunk function associated with higher classification groups. For this reason, similar situations may come about in WB so the athletes who spent a greater percentage of their training time doing high-intensity exercise, the objective (HR-based TL) equations may overestimate training load compared with the subjective (RPE-based TL) method (Borresen et al., 2008).

According to the individual correlations there were significant correlations between both HR-based ML and RPE-based ML in most of the cases, nevertheless, no correlations were found in several cases concerning different disabilities. Lupo et al. (2014) reported high individual correlations (r = 0.76 – 0.98, R^2 = 0.58 – 0.97, $p < 0.05$) in water polo training tasks. Impellizzeri et al. (2004) found moderate correlations (r = 0.50 to 0.85 for individuals) between training loads calculated using the RPE-based TL and the HR-based TL for members of a club soccer team. These individual high correlations also were observed in basketball training tasks between Edward's TL and RPE-based TL methods (r = 0.69 to 0.85 for individuals) (Manzi et al., 2010). In the study of Scanlan et al. (2014) the sRPE TL model was significantly correlated with the Banisters' training impulse model (r = 0.80, p< 0.05) and Edwards' TL model (r = 0.89, p< 0.05) across all sessions. Generally, our results are lower than those observed by these authors

(Lupo et al., 2014; Manzi et al., 2010; Scanlan et al., 2014; Impellizzeri et al., 2004). However, in this study, as we mention above, not all of WB players obtained significant correlations.

In the recent literature regarding different disabilities, some studies corroborated the relationship between RPE and other physiological markers in laboratory environments, but not in a real game situation, nor in training sessions in WB (Al-Rahamneh et al., 2010; Al-Rahamneh & Eston, 2011; Goosey-Tolfrey et al., 2010b). Paulson et al. (2013) reported strong linear relationships between VO_2 and local (r = 0.91), central (r = 0.88) and overall RPE (r = 0.90) in eight male wheelchair dependent participants with a cervical SCI at C5/6. Although these laboratory studies support the use of RPE as a tool to self regulate the intensity of wheelchair propulsive exercise, more studies are necessary in an intermittent exercise situation in WB to determine the validity of a subjective method to quantify the match load. As we explained above, even if the whole team obtained moderate correlation between RPE-based ML and HR-based ML methods, not all of WB players obtained significant correlations, for this reason, it would be interesting to pursue this issue and determine which injury type correlates better. Thus, we could improve current training methods and optimize sport-specific training.

6.6. Conclusions

Our results suggest that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players. This method is cost effective and a practical tool that any coach could administer as long as they were confident that the players had been familiarized to the 0-10 RPE scale. That said, since only ≥40% of variance in HR-based ML was explained by RPE-based ML then although RPE could be considered a proxy measure of ML it should not be seen as a substitute of HR. This may be explained by the sample recruited, since large heterogeneity of physical impairment types existed which is typical to the make-up of a WB team. This is likely to have influenced the subjective methods of quantifying ML. This warrants further attention and future studies should explore whether there are different RPE responses of players with a spinal cord injury compared to those with a non-spinal injury so that match play and training quantification can be accurately reported via subjective measures.

7. ZAZPIGARREN KAPITULUA

ONDORIO OROKORRAK

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1. Gurpildun aulkiko saskibaloiko denboraldian zehar aldaketak ikusi dira gorputz konposizioan eta errendimendu fisikoan; baloiarekin egindako azelerazio ahalmenean, indarra, eta erresistentziako testean egindako distantzian. Hala ere, ez da hobekuntzarik ikusi baloirik gabeko azelerazioan, norabidez aldatzeko ahalmenean eta indar explosiboan. Baliteke entrenatzaile eta prestatzaile fisikoek indar entrenamendua erabili behar izatea gurpildun aulkiko saskibaloi jokalarien ahalmen hauek hobetzeko.

2. Gurpildun aulkiko saskibaloiko joko murriztuetan ez da erlazio adierazgarririk aurkitu barne karga neurtzeko metodo objektibo eta subjektiboen artean. Beraz, gurpildun aulkiko saskibaloiko talde honetan bi metodoak independienteki hausnartu beharko dira informazio guztiz ezberdina ahalbidetzen digutelako. Hala ere, bi metodoak osagarriak izan daitezke eta metodo bakoitzaren limitazioak ulertzen lagun dezakete. Banakako koerlazioak ezberdinak dira jokalarien artean, baliteke emaitza hauek urritasunen aniztasunak eta *IWBF* sailkapenak eragin izana; beraz, urritasunek, bihotz maiztasunaren eta nekearen hautemate erantzunen arteko erlazioan izan dezaketen influentzia ikertzea interesgarria litzateke.

3. Gurpildun aulkiko saskibaloiko joko murriztuetan bizkar muineko lesioa duten jokalariek bihotz maiztasun absolutu baxuagoa erakutsi dute bizkar muineko lesioa ez duten jokalariek baino. Hala ere, ikerketaren ondorio nagusia, bihotz maiztasunaren balore erlatiboetan aurkitzen da, non, bizkar muineko lesioa duten jokalariek bizkar muineko lesiorik gabeko jokalarien antzeko baloreak izan dituzten. Hautemandako nekeari dagokionez, azken errepikapenean bizkar muineko lesioa duten jokalariek balore altuagoak erakutsi dituzte bizkar muineko lesiorik gabeko jokalariak baino. Metodo objektibo eta subjektiboen arteko joera ezberdinek bizkar muineko lesioa duten jokalariekin egindako ikerketa gehiagoren beharra adierazten du, bihotz maiztasun eta hautemandako nekea aztertuz.

4. Subjektiboki hautemandako nekea neurtzeko erabiltzen diren metodoak erabilgarriak izan daitezkela erakusten dute emaitzek. Metodo hau, merkea nahiz praktikoa da, edozein entrenatzailek familiarizatuta dauden jokalariekin erabil dezaketena. Metodo subjektiboek metodo objektiboen %40 azaltzen dute, beraz, ordezkaezinak izango dira; baina, gehigarriak direla esan daiteke. Baliteke, urritasun fisikoan dagoen heteroegeneitateak metodo subjektiboetan influentzia izatea. Hau dela eta, etorkizuneko ikerketek urritasun fisikoek metodo subjektiboetan izan ditzaketen influentzia aztertu beharko lukete; bizkar muineko lesioa dutenen eta ez dutenen arteko konparaketa adibidez. Honela, barne karga kuantifikatzeko ahal den eta zehaztasun handiena erabili ahalko zen.

8. ZORTZIGARREN KAPITULUA

ETORKIZUNEKO IKERKETA BIDEA

ETORKIZUNEKO IKERKETA BIDEA

Gaur egun, teknologiaren garapenak, mugimenduaren azterketa eta eskaera fisiologikoak aztertzeko aukera ematen du. Entrenamenduaren efektua ikusteko interesgarria izango litzateke entrenamenduaren barne karga kuantifikatu eta barne karga horrek egoera fisikoan duen influentzia neurtzea. Kontuan izatekoa da ordea, bizkar muineko lesioa duten jokalariek behar bereziak izan ditzaketen edo ez analizatzea premiazkoa suerta daitekeela.
Lesio bakoitzaren ezaugarriak aztertzeko lagin handiagoko ikerketak beharko lirateke. Laginaren heteroegeneitatea urritasunen arabera edo IWBF puntuazio sistemaren arabera sailkatuz, entrenamendu, entrenamendu tarea eta partiduetan__barne kargaren analisi zehatzagoa eskuratuko litzateke.
Beste alde batetik, bizkar muineko lesioa duten pertsonetan antropometriaren eta errendimendu fisikoaren arteko erlazioa ikertzea ikerketa bide interesgarri bat izango litzateke.

Joko murriztuen ildotik, 4vs4 egoeran egindakoa bakarrik aztertu da. Interesgarria litzateke 1vs1, 2vs2, 3vs3, 4vs4 eta 5vs5 egoeretan barne karga aztertzea; alde batetik, zelai osoan zehar edota espazioaren tamaina alderatuz eta bestetik, jokalarien espazio indibiduala errespetatuz. Honetaz gain, joko murriztuek errendimendu fisikoan duten eragina ikertzea oso interesgarria litzateke.

Kanpo kargaren analisiaren bidez, azelerazio eta dezelerazioak, abidura ezberdinak plano ezberdinetan, abiadura maximoak, sprinten kopurua, lor daitezke, beste hainbat aldagaien artean. Horregatik, oso interesgarria litzateke kanpo kargaren analisia egitea entrenamendu tarea, entrenamendu eta partidutan. Honela, gurpildun aulkiko saskibaloiaren eskaera fisiko eta fisiologikoak gehiago ulertuko ziren eta ondorioz jokalarien errendimendua hobetzeko herraminta gehiago izango dira. Bestalde, partiduetan arerioaren mailaren araberako azterketa eta urritasun ezberdinen arteko ezberdintasunak ikertzea interesgarria litzateke. Hala ere, honetarako lagin handia izatea beharrezkoa litzateke entrenatzaileei eta prestatzeaile fisikoei berme handiago bat emango diotelako ikerketen emaitzek.

Azkenik, errrendimendu fisikoa hobetzeko helburuarekin ikerketa multidisziplinarrean oinarritutako interbentzio programak sortzea interesgarria izango litzatekela gaineratu behar da, errendimendua eta osasuna uztartuz.

9. BEDERATZIGARREN KAPITULUA

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10. HAMARGARREN KAPITULUA

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10.1. LEHENENGO ERANSKINA: *Kalitate adierazleak*

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JSS	0264-0414	Ingalaterra	Kirol zientziak	2.099	2.888	2
SC	1362-4393	Ingalaterra	Erreabilitazioa	1.751	1.876	2
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10.2. BIGARREN ERANSKINA: *Aldizkarietako argitalpenak*

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Sport and Disabled Individuals – Theory and Practice

DE GRUYTER OPEN

Changes in Body Composition and Physical Performance in Wheelchair Basketball Players During a Competitive Season

by
Aitor Iturricastillo[1], Cristina Granados[1], Javier Yanci[1]

The present study analyzed the changes in body composition and physical performance in wheelchair basketball (WB) players during one competitive season. Players from a WB team competing in the first division of the Spanish League (n = 8, age: 26.5 ± 2.9 years, body mass: 79.8 ± 12.6 kg, sitting height: 91.4 ± 4.4 cm) participated in this research. The upper limbs showed a decrease in subcutaneous adipose tissue and there was an improvement in physical abilities such as sprinting with the ball (5 and 20 m), handgrip and aerobic capacity. However, the changes in physical fitness concerning sprinting without the ball and agility tests were low. It would be interesting to study the effects of implementing specific programs to improve physical performance in WB and to establish more test sessions to monitor the effects of the programs followed.

***Key words**: adapted sports, anthropometrics, skinfolds, physical performance, field tests.*

Introduction

Wheelchair basketball (WB) is one of the most popular sports among the Paralympic disciplines and is practiced by people with different disabilities, according to the classification protocol of the International Wheelchair Basketball Federation (IWBF). WB is an intermittent sport which combines repeated high intensity sprints and rapid accelerations and decelerations with moderate and low intensity actions, with the purpose, among other aims, of achieving or maintaining a good position on the court (Molik et al., 2010). In this sense, both anaerobic and aerobic capacities are important for a better performance, during offensive and defensive situations (Molik et al., 2013). Body composition is also a significant factor affecting performance in WB.

Several studies have determined the importance of anthropometry in sport, and it is perhaps even greater in adapted sports, where certain players with spinal cord injury may experience a loss of metabolic activity in active fibers and muscle mass due to their particular injury (Collins et al., 2010). For this reason some authors have studied body composition using skin folds in wheelchair basketball and tennis players (Sutton et al., 2009). In this regard, some researchers have stated that both the player's functional potential (Vanlandewijck et al., 2004) and their body composition (Goosey-Tolfrey et al., 2003) will influence physical performance in WB. Therefore, it could be important for coaches to study the evolution of the anthropometric characteristics of WB players during a competitive season.

Several articles have describe the physical qualities of WB players under laboratory conditions (Goosey-Tolfrey et al., 2003; Goosey-Tolfrey et al., 2008; Molik et al., 2010) and also using field tests carried out in their own playing area (De Groot et al., 2012; Vanlandewijck et al., 1999). Among the field tests, the most important are those that measure sprint capacity, change of direction ability and muscle strength (Goosey-Tolfrey et al., 2008; Molik et al., 2013; Yanci et al., 2015), and obviously those that measure aerobic

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capacity (Goosey-Tolfrey and Tolfrey, 2010; Vanlandewick et al., 1999). However, we have only found one study which monitored the changes in physical fitness of WB players (Ayán et al., 2014). Given the absence of research to corroborate these findings, more studies on this topic are needed to analyze the changes in physical performance during a competitive season.

Therefore, the purpose of the present study was to analyze the changes in body composition and physical performance in elite WB players during one competitive season.

Material and Methods

Participants

Players from a WB team competing in the first division of the Spanish League (n = 8, age: 26.5 ± 2.9 years, body mass: 79.8 ± 12.6 kg, sitting height: 91.4 ± 4.4 cm) participated in this research. All the subjects were informed about the risks and benefits of taking part in the study, knew that they could withdraw at any time, and signed a mandatory informed consent form.

Procedures

The tests were carried out on the basketball court where the team trained. A week before the start of the official competitive season (pretest), different tests were performed to assess body composition and physical performance. At the end of the season, a week after the last league match (posttest) the same tests were repeated. On the first day the players performed the acceleration tests (5 and 20 m sprint with and without the ball) and the agility tests (T-test and Pick-Up test). On the second day (48 hours later) the measurements of body composition were taken, and the strength tests (maximal pass, medicine ball throw and handgrip) and the intermittent Yo-Yo Level 1 test of 10 m (YYIR1 10 m) were conducted. Before performing the test battery the players carried out a standard warm-up consisting of 5 min of low intensity wheelchair propulsion, two straight line accelerations of 10 m and two accelerations of 10 m with changes of direction. All the participants performed the tests in their usual wheelchair.

Test battery

Body composition

The anthropometric variables of body mass (kg) and skin folds (mm) were measured in each player. Body mass was obtained to the nearest of 0.1 kg using an electronic scale (Seca® Instruments Ltd., Hamburg, Germany) and four skin folds were measured (triceps, subscapular, suprailiac, and abdominal) with a skin fold caliper (Harpender Lange®, Cambridge, MA, USA) bearing in mind the indications specified by Goosey-Tolfrey et al. (2003). The same person recorded all the anthropometric variables on all occasions.

5 and 20 m sprints (with and without the ball)

Three accelerations were performed over 5 and 20 m in a straight line with and without the ball (De Groot et al., 2012), with a 2 min rest period between each sprint, which was enough time to return to the start and wait for their next turn. The participants were placed at 0.5 m from the starting point and began when they felt ready. The timer was activated automatically as the subjects passed the first gate at the 0.0-m mark and split times were then recorded at 5 and 20 m (Granados et al., 2015). The time taken was recorded using three photocells (Microgate® Polifemo, Bolzano, Italy). The best time was used for further analysis.

T-test

The participants had to complete a circuit in the shape of a T according to the specifications of Yanci et al. (2015) for WB players. They began with the wheels 0.5 m from cone A, and completed the circuit as follows (Figure 1A), with modifications to allow performance in a wheelchair and always using forward movements (Yanci et al., 2015). Three repetitions were performed with 3 min rest between them. The time was recorded with a photocell (Microgate® Polifemo, Bolzano, Italy). The best result was used for further analysis.

Pick-up

The test was performed three times with 3 min rest between, following the indications of De Groot et al. (2012). From a stationary position, the participant had to start propelling their chair and pick up 4 basketball balls from the floor twice with the left hand and twice with the right hand (Figure 1B). Three repetitions were performed with 3 min rest periods between them. Time was recorded using two photocells (Microgate® Polifemo, Bolzano, Italy) placed at the beginning and the end of the course. The best time was used for further analysis.

Maximal pass

The subjects lined up at the marked line, with their front wheels behind the line, and performed three bilateral throws with a basketball trying to throw it as far as possible (De Groot et al., 2012). The distance was measured (m) between the marked line and the place where the ball bounced for the first time. The final score used for the statistical analysis was the average distance of five throws (De Groot et al., 2012).

Medicine ball throw

From the same position used in the *maximal pass* test, the players had to throw the 5 kg medicine ball as far as possible (Gonaus and Muller, 2012; Yanci et al., 2015). Each player was allowed three attempts and the distance was measured in m from the throwing line to the place where the ball made its first contact with the ground. The best of the three results was used for statistical analysis.

Handgrip

Forearm strength was measured in the dominant hand (Molik et al., 2013) using a portable hydraulic hand dynamometer (5030J1, Jamar®, Sammons Preston, Inc, United Kingdom). The test was performed in a sitting position in the wheelchair, with the arm in extension and in the vertical axis. The test protocol consisted of three maximal isometric contractions of 5 s, with a rest period of at least 60 s. The best of the three recordings was used for statistical analysis.

Yo-Yo 10 m Intermittent Recovery Endurance Test

Version 1 of the Yo-Yo test (YYIR1 10 m) was used as previously described by Yanci et al. (2015) and Granados et al. (2015) for WB players. The original YYIR1 test consisted of 20 m shuttle runs performed at increasing speed with 10 s of active recovery between runs until exhaustion. Considering the differences between running and propelling the wheelchair, the distance covered in the shuttle run was modified in this study to 10 m. The total distance covered (Castagna et al., 2008), a heart rate (HR) (Polar Team Sport System®, Polar Electro Oy, Finland) and lactate concentration (Lactate Pro LT-1710®, ArkRay Inc Ltd, Kyoto, Japan) were recorded. At the end of the endurance test, the subjects were also asked to rate their perceived exertion (RPE) on a 10-point category rating scale (Foster et al., 2001), presented on paper. They were asked separately for a respiratory rate of perceived exertion (RPEres) and an arm muscle rate of perceived exertion (RPEmus) as previously used in WB (Granados et al., 2015; Iturricastillo et al., in press).

Training program and competition

During the competitive season the players competed in 16 official matches and trained twice per week. The training sessions consisted of an hour of exercise with and without the ball and the other hour was spent performing technical exercises and team tactics. The group tactics involved exercises with play situations in a more limited space and with fewer players. The training session always ended with real game situations.

Statistical analysis

The statistical analysis was carried out with the Statistical Package for Social Sciences (SPSS® Inc, version 20.0 Chicago, IL, USA.). The results are presented as mean ± standard deviation (SD). The normality of the data was analyzed with the Kolmogorov-Smirnov tests to verify the need for parametric or non-parametric tests. A t-test for related samples was used to determine the differences between the results obtained in the pre and posttest. The delta value (Δ%) between the pre and posttest was calculated using the formula: Δ% = [(Posttest-pretest)/pretest] x 100. The effect size (d) was calculated using the method proposed by Cohen (1988). Effect sizes lower than 0.2, between 0.2-0.5, between 0.5-0.8 or greater than 0.8 were considered trivial, low, moderate or high, respectively. Statistical significance was set at $p < 0.05$.

Results

Table 1 shows the results of the body composition measurements in the pre and posttest. The players increased their body mass ($p < 0.05$, d = 0.30, low), and there was a tendency, although it was not significant, for a decrease in the triceps ($p > 0.05$, d = -1.40, high) and in the subscapular ($p > 0.05$, d = -0.50, moderate) skin fold, together with an increase in the suprailiac skin fold ($p > 0.05$, d = 0.55, moderate) at the end of the season.

With regard to physical performance, Table 2 shows the results in the pre and posttest of the players' acceleration capacity with and without the ball and their agility. There was a

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tendency for improvement in acceleration over 5 m ($p > 0.05$, d = 0.79, moderate) and 20 m with the ball ($p > 0.05$, d = 0.44, low). However, no differences were found in acceleration without the ball or in agility ($p > 0.05$, range d = 0.11 – 0.33, low).

As to muscular strength, no significant differences were observed in the maximal pass distance between the pre and posttest (12.57 ± 2.10 m vs. 12.74 ± 2.41 m, $p > 0.05$, d = 0.08, trivial), or in the medicine ball throw (4.68 ± 0.54 m vs. 4.89 0.77 m, $p > 0.05$, d = 0.38, low). However, at the end of the season the players recorded better results in the handgrip test ($p > 0.05$, d = 1.26, high) than at the start of the season (Figure 1).

With respect to the results obtained in the YYIR1, no differences were found between the pre and posttest in lactate concentration (9.33 ± 4.05 vs. 8.70 ± 3.56 mmol·l-1, $p > 0.05$, d = 0.16, trivial), or in the HRmax (184.5 ± 16.2 vs. 179.2 ± 14.1 latidos·min-1, $p > 0.05$, d = 0.33, low). However, at the end of the season, the players increased their performance with regard to total distance covered, although not significantly ($p > 0.05$, d = 0.77, moderate) (Figure 2). There was also a tendency for the respiratory RPE to be lower (6.58 ± 2.01 vs. 4.67 ± 3.14, $p > 0.05$, d = 0.95, high) but not the muscular RPE (5.92 ± 2.15 vs. 5.00 ± 2.53, $p > 0.05$, d = 0.43, low) in the post compared to the pretest.

Discussion

The analysis of WB players' physical fitness can provide relevant information for the determination of their sports performance (De Groot et al., 2012; Goosey-Tolfrey, 2005; Yanci et al., 2015), as it could help coaches improve the training process. The present study analyzed the evolution of body composition and physical performance in WB players during one competitive season. The results obtained regarding body composition revealed that there was an increase in body mass and a tendency for some skin folds to decrease. In relation to physical performance, the results in some physical fitness tests (5 and 20 m with the ball, distance covered in the YYIR1 10 m, and the handgrip test) were better at the end of the competitive season.

Several studies exist which have analyzed body composition in people with spinal cord injury (Collins et al., 2010; Price, 2010) and in female WB and wheelchair tennis players (Sutton et al., 2009). However, to our knowledge, there is no study that analyzes anthropometric characteristics of WB players during a competitive season. In our study, coinciding with Burke et al. (1986) who analyzed results before and after a competitive period in Australian rules football, there was a significant increase in body mass, but a decrease in skin folds. To be precise, the upper limbs showed a decrease in subcutaneous adipose tissue possibly due to a high level of activity when propelling the wheelchair, thus coinciding with the results obtained in the study by Sutton et al. (2009) where female WB players showed a lower percentage of adipose tissue in the arms than other players who did not use a wheelchair for sport. In this sense, continuous practice of WB aimed at reducing percentage of body fat could improve their physical performance and be beneficial for their health (Collins et al., 2010). In spite of the decrease in adipose tissue observed in some skin folds in the upper body (triceps and subscapular), the players in our study increased their suprailiac and abdominal skin folds at the end of the competitive season. It could possibly be interesting for WB coaches to control nutritional intake as body composition might have more likely been affected by diet rather than training and competition. A decrease in subcutaneous adipose tissue may be due to the training effects during the whole season.

Studies concerning changes in physical performance in WB during the competition period are scarce (Ayán et al., 2014) compared with able-bodied sports (Casajús, 2001; Drinkwater et al., 2005; Marques et al., 2006). The results obtained by these authors showed that physical performance in WB players revealed practically no changes during the season (trivial or low). In our case, the results were similar in both the pre and posttest (Δ% < 1.83%, d < 0.33, trivial or low) for the sprint tests without the ball, change of direction abilities and the throwing tests. However, contrary to the results presented by Ayán et al. (2014), the players in our study did obtain better results in the sprint tests of 5 and 20 m with the ball (Δ% = 7.84%, d = 0.79 and Δ% = 3,11%, d = 0.44, respectively) and in the handgrip test (Δ% = 19.78%, d = 1.26) at the end of the season, even though they did not follow any specific training during the season to improve their strength/power.

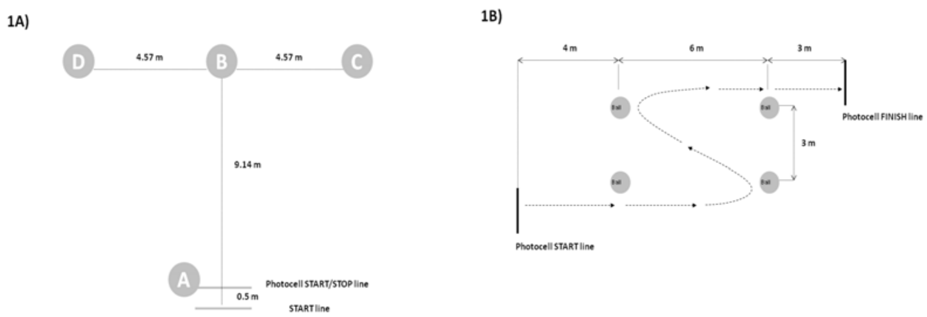

Figure 1

Agility T-test (1A) and Pick up test (1B)

Table 1

Body composition in the pre and posttest in WB basketball players

	Pretest	SD	Posttest	SD	Δ (%)	d
Body mass (kg)	74.60	9.67	76.73*	10.11	2.86	0.30
Triceps	11.37	3.42	10.83	3.98	-4.77	-1.40
Subscapular	17.26	5.66	16.77	5.47	-2.81	-0.50
Suprailiac	15.60	6.71	16.17	6.85	3.66	0.55
Abdominal	28.94	11.49	30.20	10.04	4.34	0.38
Skin folds	69.08	24.97	64.73	33.59	-6.30	-0.25

SD = standard deviation, Δ= Difference of means, d = effect size

Table 2

Results of acceleration with and without the ball, and in the tests of change of direction ability both in the pre and posttest, in WB players

	Pretest (s)	Posttest (s)	Δ (%)	d
Acceleration				
Without B 5 m	1.73 ± 0.06	1.71 ± 0.10	-1.15	0.33
Without B 20 m	5.16 ± 0.18	5.18 ± 0.21	0.39	0.11
With B 5 m	1.89 ± 0.19	1.74 ± 0.15	-7.84	0.79
With B 20 m	5.76 ± 0.41	5.58 ± 0.38	-3.10	0.44
Agility				
T-Test	14.35 ± 0.62	14.14 ± 0.58	-1.42	0.33
Pick up	11.85 ± 0.78	11.64 ± 0.67	-1.83	0.28

Δ = difference of means, d = effect size, Without B = without ball, With B = with ball

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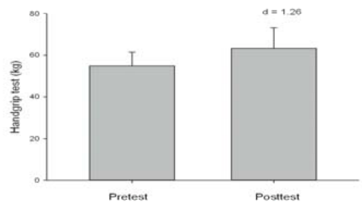

Figure 2

Mean values (± SD) obtained in the handgrip test in both the pre and posttest by WB players

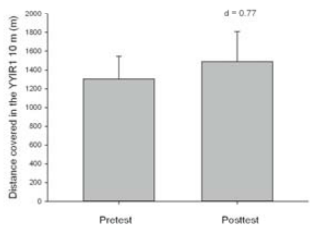

Figure 3

Distance covered in the Yo-Yo Level 1 10 m endurance test (YYIR1 10 m) in WB players

Possibly, and given that several studies on able-bodied sports had found a close association between strength and acceleration capacity (Granados et al., 2013; Rønnestad et al., 2011), and also in WB (Janssen et al., 1993; Molik et al., 2013; Turbanski and Schmidtbleicher, 2010), the absence of specific training aimed at improving strength could have influenced the lack of improvements in acceleration capacity, change of direction ability and throwing. It would therefore be interesting to analyze if including specific strength/power training sessions could produce improvements in the physical performance of WB players during the season.

Studies concerning changes in physical performance in WB during the competition period are scarce (Ayán et al., 2014) compared with able-bodied sports (Casajús, 2001; Drinkwater et al., 2005; Marques et al., 2006). The results obtained by these authors showed that physical performance in WB players revealed practically no changes during the season (trivial or low). In our case, the results were similar in both the pre and posttest (Δ% < 1.83%, d < 0.33, trivial or low) for the sprint tests without the ball, change of direction abilities and the throwing tests. However, contrary to the results presented by Ayán et al. (2014), the players in our study did obtain better results in the sprint tests of 5 and 20 m with the ball (Δ% = 7.84%, d = 0.79 and Δ% = 3,11%, d = 0.44, respectively) and in the handgrip test (Δ% = 19.78%, d = 1.26) at the end of the season, even though they did not follow any specific training during the season to improve their strength/power. Possibly, and given that several studies on able-bodied sports had found a close association between strength and acceleration capacity (Granados et al., 2013; Rønnestad et al., 2011), and also in WB (Janssen et al., 1993; Molik et al., 2013; Turbanski and Schmidtbleicher, 2010), the absence of specific training aimed at improving strength could have influenced the lack of improvements in acceleration capacity, change of direction ability and throwing. It would therefore be interesting to analyze if including specific strength/power training sessions could produce improvements in the physical performance of WB players during the season.

Aerobic capacity has also been studied in WB by different authors (Goosey-Tolfrey et al., 2008; Vanlandewick et al., 1999) due to its importance for the sport. In spite of the fact that field tests to measure changes in aerobic capacity have been widely applied in able-bodied team sports, only few papers have studied this quality in WB (Ayán al., 2015). Our results indicate that there was an improvement in the YYIR1 test at the end of the season, although it was not significant (Δ% = 14.73%, d = 0.77). Furthermore, the players who participated in our study showed lower levels of lactate concentration in the posttest (9.33 ± 4.05 mmol·l-1 vs. 8.70 ± 3.56 mmol·l-1). In this sense, WB players recorded a better performance in the YYIR1 and had better physiological responses at the end of the season; thus, the improvement in the YYIR1 test at the end of the season could indicate an improvement in aerobic capacity. There was also an improvement in their RPE, especially their RPEres (Δ% = 29.03%, d = 0.95), therefore, this fact confirms the better performance in the aerobic test at the end compared to the beginning of the season. These results are quite similar to those obtained by Ayán et al. (2012) as the latter state that they did not observe important changes in the multi stage fitness test (MSFT) at three different time points in the WB season (p = 0.683; Δ% = 10.40). Possibly the nature and typology of the tests used, the internal and external load in the training sessions and matches, as well as body composition at the respective moment could have influenced the obtained results. In this sense, it would be interesting to study the effects of implementing specific programs to improve physical performance in WB and to establish more test sessions to monitor the effects of the programs followed.

The obtained results should be interpreted with caution due to some important limitations of the study. First of all, nutritional intake during the whole season was not controlled, and the body composition changes might have been due to diet rather than training and competition. Moreover, a control group could have provided us with exact data on the training effects for physical fitness, which is why it would be interesting for future research to include one.

Conclusions

In our study the WB players showed changes during the season in some variables of

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body composition and physical fitness, i.e. in acceleration capacity over 5 and 20 m with the ball, strength, the handgrip test, and the total distance covered in the endurance test. However, no differences were observed in acceleration capacity without the ball, change of direction ability, or explosive strength. Coaches of WB teams should consider the need to implement additional specific training sessions to improve these abilities in WB players.

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Objective and subjective methods for quantifying training load in wheelchair basketball small-sided games

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Objective and subjective methods for quantifying training load in wheelchair basketball small-sided games

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ABSTRACT

The aim of the present study was to analyse the training load in wheelchair basketball small-sided games and determine the relationship between heart rate (HR)-based training load and perceived exertion (RPE)-based training load methods among small-sided games bouts. HR-based measurements of training load included Edwards' training load and Stagno's training impulses ($TRIMP_{MOD}$) while RPE-based training load measurements included cardiopulmonary (session RPEres) and muscular (session RPEmus) values. Data were collected from 12 wheelchair basketball players during five consecutive weeks. The total load for the small-sided games sessions was 67.5 ± 6.7 and 55.3 ± 12.5 AU in HR-based training load (Edwards' training load and $TRIMP_{MOD}$), while the RPE-based training loads were 99.3 ± 26.9 (session RPEres) and 100.8 ± 31.2 AU (session RPEmus). Bout-to-bout analysis identified greater session RPEmus in the third [$P < 0.05$; effect size (ES) = 0.66, moderate] and fourth bouts ($P < 0.05$; ES = 0.64, moderate) than in the first bout, but other measures did not differ. Mean correlations indicated a trivial and small relationship among HR-based and RPE-based training loads. It is suggested that HR-based and RPE-based training loads provide different information, but these two methods could be complementary because one method could help us to understand the limitations of the other.

ARTICLE HISTORY
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KEYWORDS
Para-sport; training tasks; rating of perceived exertion; heart rate; training load

Introduction

Over the last decade, a new approach to improving team sport athletes' fitness has been developed in the form of game-based conditioning (Klusemann, Pyne, Foster, & Drinkwater, 2012). According to these authors (Klusemann et al., 2012), small-sided games provide greater transfer of physiological adaptations as training simulates the movement patterns that athletes perform in competition. Moreover, this type of training allows simultaneous technical, tactical and physical training, and also seems to be a task that improves motivation and enjoyment for athletes over interval training (Los Arcos et al., 2015b). However, we do not know how these psychological responses could be transferred to competition. Although there are several studies on small-sided games in able-bodied team sports such as football (Campos-Vazquez et al., 2015; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011), handball (Buchheit et al., 2009; Corvino, Tessitore, Minganti, & Sibila, 2014) and basketball (Castagna, Impellizzeri, Chaouachi, Ben Abdelkrim, & Manzi, 2011; Delextrat & Kraiem, 2013; Sampaio, Abrantes, & Leite, 2009), few studies have investigated in adapted team sports (Yanci, Iturricastillo, & Granados, 2014). In able-bodied basketball, for example, small-sided games have been extensively analysed (Castagna et al., 2011; Delextrat & Kraiem, 2013; Sampaio et al., 2009), but there are practically no studies on wheelchair basketball (Yanci et al., 2014).

To quantify training load in basketball, heart rate (HR) has been used (Delextrat & Kraiem, 2013; Sampaio et al., 2009). Nevertheless, because of limitations in quantifying load by mean HR and maximal HR or peak HR, several authors have proposed other methods that improve assessments of training demand (Edwards, 1993; Stagno, Thatcher, & Van Someren, 2007). These authors quantified demands of interval training by summating HR zones and giving a final value for each training session or training task. In addition, in recent decades, the HR has been supplemented by a subjective measure of training load such as an athlete's overall session rating for perceived exertion (RPE) (Foster et al., 2001). Many studies have analysed overall RPE in able-bodied team sports (Coutts, Rampinini, Marcora, Castagna, & Imperizzelli, 2009), but in spite of the increasing number of investigations into subjective measures of internal load in adapted physical activity and sports (Al-Rahamned & Eston, 2011; Paulson, Mason, Rhodes, & Goosey-Tolfrey, 2015; Qi, Ferguson-Pell, Salimi, Haennel, & Ramadi, 2015), to the best of our knowledge no studies have examined RPE and small-sided games (or intermittent high-intensity training tasks).

Various studies have validated subjective methods in different team sports (Foster et al., 2001; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004) and especially in basketball (Manzi et al., 2010; Scanlan, Wen, Tucker, Borges, & Dalbo, 2014). Strong relationships between objective and subjective

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methods have been reported. Manzi et al. (2010) reported high correlations in basketball training tasks between objective and subjective methods (r = 0.69–0.85 for all participants). Scanlan et al. (2014) reported similar findings; the subjective method correlated with the objective method (r = 0.80–0.89). However, little is known about the association between HR and RPE methods in intermittent activities in wheelchair basketball players (Iturricastillo, Yanci, Granados, & Goosey-Tolfrey, 2016). These authors showed moderate correlations between HR-based methods and RPE-based methods (r = 0.63–0.67, R^2 = 0.40–0.45, P < 0.001) in wheelchair basketball matches, but there were no relationships in players with polio and high spinal cord injury (SCI) (complete T1–T2). It is well known that players with high SCI cannot provoke high HR values (Goosey-Tolfrey & Leicht, 2013). Thus, it would be useful to know if RPE-based methods are valid in wheelchair basketball for quantifying responses to intermittent high-intensity exercise such as a small-sided games task. The ability to monitor exercise intensity during wheelchair basketball training can be used to provide important feedback to the coach about the potency of training stimuli applied to players.

Thus, the aim of the present study was to analyse the training load in wheelchair basketball small-sided games by means of objective (i.e., HR) and subjective (i.e., RPE) methods and to determine the evolution of the training load between small-sided games bouts. The second aim of the study was to determine the relationship between session RPE training load and HR-based training load and so evaluate the use of session RPE training load for assessing global exercise intensity during wheelchair basketball-specific small-sided games.

Methods

Participants

Twelve Spanish First Division wheelchair basketball players (age 31.0 ± 9.3 years, injury time 19.1 ± 13.5 years, training experience 8.6 ± 7.8 years, peak HR 177.7 ± 13.5 beats·min^{-1}) participated in the study. The inclusion criterion for the participants in the study was possession of a valid licence from the Spanish Federation of Sports for People with Physical Impairments. The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF) (Table 1). Before their involvement, all participants gave written informed consent after a detailed written and oral explanation of the potential risks and benefits from participation in this study had been given, as outlined in the Declaration of Helsinki (2013). The participants had the option to withdraw from the study at any time. The Ethics Committee of the University of the Basque Country (UPV/EHU) approved the study.

Procedures

The study was conducted over five consecutive weeks during the competitive period (November–December, season 2013–2014), when the team had five matches (fixtures 2, 3, 4, 5 and 6) during these weeks. The players undertook two training sessions and one official match per week. However, not all played every match or the same duration. Furthermore, none of these players was taking part in additional strength and conditioning sessions at the time of the study. The HR- and RPE-based training load of a full-court 4 versus 4 small-sided games were quantified. The small-sided games were part of the training sessions, so data were collected during the five consecutive Tuesdays at the same time of day (8–9 PM) and with at least 48 h rest between sessions. The small-sided games were performed on a basketball court (15 × 28 m). The duration (4 × 4 min separated by 2 min of passive recovery) of each small-sided games was strictly controlled as implemented by others (Dellal, Jannault, Lopez-Segovia, & Pialoux, 2011) and in wheelchair basketball (Yanci et al., 2014). The teams were balanced for impairment and according to the IWBF functional classification. Thus, players with SCI were intermixed with players without SCI. Moreover, there were no player changes during the same session. A total of 32 individual small-sided games sessions met all requirements, thus data from 128 individual bouts were included in the analysis.

Endurance test

To obtain the individual peak HR of each player, all completed a 10 m Yo-Yo intermittent recovery test, level 1, as previously used in wheelchair basketball (Yanci et al., 2015), 1 week before the competition period. This endurance test has good reproducibility (intraclass correlation coefficient = 0.83–0.94 and coefficients of variation from 2.6% to 7.2%) (Yanci et al., 2015). Pushing speeds were dictated in the form of audio cues

Table 1. Wheelchair basketball players' characteristics.

Player	Injury	Age (years)	IWBF classification	Injury time (years)	Injury time (years)
1	Spina bífida (L1)	16	1	16	16
2	Spinal cord injury (T1–T2)	36	1	34	34
3	Spinal cord injury (T12–L3)	42	1	18	18
4	Spinal cord injury (T3)	19	1	12	12
5	Spinal cord injury (incomplete, C5–C6)	35	3	30	30
6	Spinal cord injury (T10)	30	3	2	2
7	Viral disease (polio)	35	3.5	33	33
8	Osteoarthritis congenital	40	4	40	40
9	Amputation	35	4	28	28
10	Hip labral tear	18	4.5	2	2
11	Knee injury	41	4.5	9	9
12	Knee injury	25	4.5	5	5
Sample (n = 12)		31 ± 9.3	–	19.1 ± 13.5	19.1 ± 13.5

IWBF: International Wheelchair Basketball Federation.

broadcast by a pre-programmed computer. The test was considered to have ended when the participant failed twice to reach the front line in time (objective evaluation) or felt unable to cover another shuttle at the dictated speed (subjective evaluation). In any case, all players were accustomed to the field-testing procedures as they were part of their usual fitness assessment programme. During the test, HR was continuously monitored at 1 s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). The peak HR was determined from the highest value obtained by each player either in the YYIR1 or the small-sided games (Table 2).

Determination of small-sided games training load

We determined the training load (arbitrary units, AU) for each player during each small-sided games by four methods used previously in team sports and in wheelchair basketball (Iturricastillo et al., 2016). Specifically, two HR-based methods, Edwards (1993) and TRIMP$_{MOD}$ (Stagno et al., 2007), and two other RPE-based methods, perceived cardiopulmonary training load (session RPEres) and perceived muscular training load (session RPEmus) (Iturricastillo et al., 2016; Los Arcos, Martínez-Santos, Yanci, Mendiguchia, & Mendez-Villanueva, 2015a; Los Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014), were used to quantify training load. The HR was continuously monitored throughout the small-sided games at 1 s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). Duration of play was investigated, so no rest times were included in this study.

Edwards' training load method

Edwards' (1993) method includes the total volume of training and considers five zones of intensity. The calculation was performed for each session by multiplying the accumulated time (min) in each HR zone for a value assigned to each intensity zone (90–100% peak HR = 5, 80–89% peak HR = 4, 70–79% peak HR = 3, 60–69% peak HR = 2, 50–59% peak HR = 1), and finally summarising the results (Edwards, 1993; Iturricastillo et al., 2016).

TRIMP$_{MOD}$ method

TRIMP calculation was also performed as proposed by Stagno et al. (2007). The training load is determined by calculating the result of multiplying the training duration (min) in each of the current zones by the weighting factor for each zone (93–100% peak HR = 5.16; 86–92% peak HR = 3.61; 79–85% peak HR = 2.54; 72–78% peak HR = 1.71; 65–71% peak HR = 1.25), and finally summarising the results.

Perceived exertion-based methods

The 10-point scale proposed by Foster et al. (2001) was administered at the end of each bout. Players responded separately about the cardiopulmonary RPE and the muscle RPE (Iturricastillo et al., 2016; Paulson et al., 2015; Qi et al., 2015). The specific question asked to the wheelchair basketball players for the RPE was: *how hard was this bout for you in relation to cardiopulmonary or muscular exertion?* Furthermore, other players were not aware of the RPE scores. Afterwards, RPEres and RPEmus values were multiplied by the total duration of the small-sided games bouts (min), according to Foster et al. (2001), to quantify the RPE-derived training load exposed as session RPEres and session RPEmus. Players were informed about the 10-point scale before the data collection for this study for a month, and it was used in all types of training sessions and matches.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used for calculating the mean and standard deviations (SD). Data were screened for normality of distribution and homogeneity of variances using Shapiro–Wilk and Levene's, respectively. This test showed equal variance, so parametric tests were used thereafter. Differences between small-sided games bouts in each dependent variable, including Edwards' training load, TRIMP$_{MOD}$, session RPEres and session RPEmus, were analysed using a one-way within-participants analysis of variance, followed by Bonferroni's post hoc test. The effect size (ES) was calculated using the method proposed by Cohen (1988). ESs <0.2, between 0.2 and 0.5, between 0.5 and 0.8 or >0.8 were considered trivial, small, moderate or large, respectively. The relationships between HR-based training load methods and RPE-based training load scores were assessed using Pearson's product moment correlation (*r*), as well as the confidence limits (CLs, 90%) and the coefficient of determination (R^2). The following scale of magnitudes was used to evaluate correlation coefficients: <0.1, trivial; = 0.1–0.3, small; <0.3–0.5, moderate; <0.5–0.7, large; <0.7–0.9, very large; and <0.9–1.0, almost perfect (Hopkins, Marshall, Batterham, & Hanin, 2009). Moreover, the coefficient of variation (V%) about regression was calculated using the formula: V% = [standard error of the estimate/mean of the outcome measure] × 100 (Winter & Hamley, 1976) . The $P < 0.05$ criterion was used for establishing statistical significance.

Results

The training load for the small-sided games session (i.e., the total of the four bouts) was 67.5 ± 6.7 AU and 55.3 ± 12.5 AU in HR-based training load (Edwards' training load and TRIMP$_{MOD}$, respectively). Moreover, the perceived training loads were 99.3 ± 26.9 AU (session RPEres) and 100.8 ± 31.2 AU (session RPEmus). In the bout-to-bout analysis, greater perceived muscular training load occurred in the third ($P < 0.05$; ES = 0.66, moderate) and fourth bouts ($P < 0.05$; ES = 0.64, moderate) than in the first bout (Table 3). However, there were no differences among bouts in HR-based training load ($P > 0.05$; range ES = −0.12 to 0.39, trivial to small) and session RPEres ($P > 0.05$; range ES = −0.02 to 0.51, trivial to moderate).

The mean correlations indicated a very poor relationship between HR-based training load and differential RPE-based training load. In addition, according to individual correlations, there were high correlations between HR-based training load and RPE-based training load in player 6 (r = 0.58, large; R^2 = 0.34; V% = 7.1%; $P < 0.05$; injury = SCI T10; IWBF classification = 3) and player 7 (r = 0.48 and 0.62, moderate

Table 2. Heart rate and rating of perceived exertion responses to the modified Yo-Yo intermittent recovery test 1 (modified YYIR1) and peak HR values during small-sided games.

Player	Modified YYIR1 (peak HR) (beat·min^{-1})	Peak HR during SSG (beat·min^{-1})	Percentage of peak HR reached during SSG (%)	RPEres	RPEmus
1	180	181	100.6	9.5	9
2	154	131	85.1	6	9
3	191	180	94.2	5	4
4	188	190	101.1	6	8
5	169	168	99.4	8	9
6	159	153	96.2	8	8
7	176	180	102.3	4	4
8	179	172	96.1	7	5
9	185	175	94.6	9	7
10	203	193	95.1	2	8
11	169	179	105.9	9	9
12	182	184	101.1	8.5	9
Sample (n = 12)	177.9 ± 13.7	173.8 ± 17.0	97.6 ± 5.4	6.8 ± 2.3	7.4 ± 2.0

HR: heart rate; RPEres: cardiopulmonary perceived exertion; RPEmus: muscular perceived exertion; SSG: small-sided games.

Table 3. Heart rate-based and perceived-based training load models during 4 versus 4 small-sided games.

Method	Bout 1 (32 individual bouts)	Bout 2 (32 individual bouts)	Bout 3 (32 individual bouts)	Bout 4 (32 individual bouts)	Total 4 × 4 SSG
Edwards' training load (AU)	16.5 ± 1.9 (24.5)	16.9 ± 1.7 (25)	17.1 ± 1.8 (25.4)	17.0 ± 1.9 (25.1)	67.5 ± 6.7
$TRIMP_{MOD}$ (AU)	13.1 ± 3.3 (23.7)	13.9 ± 3.4 (25.1)	14.4 ± 3.4 (25.9)	14.0 ± 3.5 (25.3)	55.3 ± 12.5
Session RPEres (AU)	22.3 ± 7.7 (22.4)	24.8 ± 7.3 (24.9)	26.2 ± 6.6 (26.4)	26.1 ± 7.1 (26.3)	99.3 ± 26.9
Session RPEmus (AU)	21.4 ± 8.9 (21.1)	25.1 ± 8.0 (24.9)	27.3 ± 8.0* (27.1)	27.1 ± 8.2* (26.9)	100.8 ± 31.2

Values are means ± SD.
Values within parentheses show % of the total training load.
SSG: small-sided games; Session RPEres: perceived cardiopulmonary training load; Session RPEmus: perceived muscular training load; $TRIMP_{MOD}$: modified training impulse; AU = arbitrary units.
*P < 0.05 significant differences compared to bout 1.

and large; R^2 = 0.39 and 0.23; V% = 6.1 and 14.7%; P < 0.05; injury = polio; IWBF classification = 3.5), but there were none in most players (Table 4). There were high correlations between Edwards' training load and Stagno's $TRIMP_{MOD}$, but not in player 2 (injury = SCI T1–T2; IWBF classification = 1), player 7 (injury = polio; IWBF classification = 3.5), player 11 (injury = knee injury; IWBF classification = 4.5) and player 12 (injury = knee injury; IWBF classification = 4.5). As regards session RPEres and session RPEmus, there were high correlations in five individuals (two players with SCI and three players with non-SCI).

According to the wheelchair basketball team observations (Table 5), there were very high correlations between Edwards' and Stagno's $TRIMP_{MOD}$ training loads in every bout (r range = 0.94; ±0.04 to 0.98; ±0.03; range R^2 = 0.81–0.95; range V% = 2.3–3.9%; P < 0.001) and in the total of the small-sided games (r = 0.96; ±0.01; R^2 = 0.92; V% = 3.1%; P < 0.001). Moreover, there were high correlations between session RPEres and session RPEmus in every bout (r range = 0.74; ±0.14 to 0.78; ±0.12; range R^2 = 0.55–0.61; range V% = 16.2–23.5%; P < 0.001) and in the total of the small-sided games (r = 0.78; ±0.06; R^2 = 0.60; V% = 18.5%; P < 0.001). Nevertheless, there were trivial or small correlations between HR-based training load and RPE-based training load methods in any bout or in the total of the small-sided games (range r = −0.30; ±0.27 to 0.26; ±0.28; range R^2 = 0.00–0.09; range V% = 10.0–29.9%; P > 0.05).

Discussion

The training load has been analysed in many team sports, including relationships between objective and subjective methods. The RPE-based training load method has been widely correlated with the HR-based training load score in many sport-training tasks (Impellizzeri et al., 2004; Manzi et al., 2010; Scanlan et al., 2014). Nevertheless, there have been few studies in relation to wheelchair basketball in spite of the importance of quantifying the load in an adapted team sport (Iturricastillo et al., 2016). Thus, the current study described the training load and investigated the relationship between HR-based training load and RPE-based training load methods in wheelchair basketball players during small-sided games. The main findings of this study were (a) HR-based training load and session RPEres were stable during small-sided games bouts while session RPEmus increased in the final bouts; (b) there were no correlations in almost all the individuals between objective and subjective methods. Thus, the session RPEres and session RPEmus provide useful information to the objective values; however, caution should be applied when using and interpreting only one of these methods during wheelchair training tasks.

The bout-to-bout analyses (RPE-based training load and HR-based training load), the objective training load and session RPEres were stable from 1 to 4 bouts while the session RPEmus was greater in the third and fourth bouts than in the first one. This might arise from wheelchair basketball small-sided games

Table 4. Individual correlations [±90% confident limit (CL)] between heart rate-based and perceived exertion based training load during 4 versus 4 small-sided games.

	Edwards		TRIMP$_{MOD}$		Edwards	Session RPEres
Player	Session RPEres *r*; ±CL (R^2) *V* (%)	Session RPEmus *r*; ±CL (R^2) *V* (%)	Session RPEres *r*; ±CL (R^2) *V* (%)	Session RPEmus *r*; ±CL (R^2) *V* (%)	TRIMP$_{MOD}$ *r*; ±CL (R^2) *V* (%)	Session RPEmus *r*; ±CL (R^2) *V* (%)
1	−0.12; ± 0.49 (0.015) 11.1%	0.05; ± 0.50 (0.002) 11.1%	−0.11; ± 0.49 (0.013) 24.2%	0.10; ± 0.50 (0.009) 24.2%	0.99; ± 0.01*** (0.973) 1.8%	0.73; ± 0.27** (0.538) 7.5%
2	−0.55; ± 0.28 (0.300) 1.8%	0.90; ± 0.08 (0.817) 1.0%	−0.88; ± 0.10 (0.773) 0.8%	0.17; ± 0.37 (0.030) 1.5%	0.13; ± 0.37 (0.018) 2.1%	−0.46; ± 0.31 (0.207) 9.3%
3	−0.40; ± 0.56 (0.156) 5.3%	−0.34; ± 0.58 (0.112) 5.4%	−0.61; ± 0.46 (0.372) 8.1%	−0.37; ± 0.57 (0.136) 9.5%	0.88; ± 0.20 (0.765) 2.8%	0.91; ± 0.16 (0.828) 4.7%
4	0.05; ± 0.63 (0.002) 5.4%	−0.69; ± 0.40 (0.478) 3.9%	0.16; ± 0.62 (0.025) 11.1%	−0.69; ± 0.40 (0.476) 8.2%	0.97; ± 0.06* (0.933) 1.4%	0.58; ± 0.48 (0.333) 6.9%
5	0.53; ± 0.88 (0.275) 5.1%	0.68; ± 0.83 (0.461) 4.3%	0.53; ± 0.88 (0.276) 11.7%	0.68; ± 0.83 (0.468) 10.0%	0.96; ± 0.35***(0.920) 1.7%	0.97; ± 0.29*** (0.945) 7.7%
6	0.58; ± 0.36* (0.338) 7.1%	0.50; ± 0.40 (0.247) 7.7%	0.57; ± 0.37 (0.324) 16.7%	0.44; ± 0.42 (0.196) 18.2%	0.97; ± 0.04*** (0.940) 2.2%	0.55; ± 0.38 (0.302) 7.6%
7	0.43; ± 0.90 (0.185) 7.0%	0.62; ± 0.83** (0386) 6.1%	0.48; ± 0.89* (0.235) 14.7%	0.66; ± 0.84** (0.429) 12.7%	0.97; ± 0.29*** (0.937) 4.4%	0.80; ± 0.74*** (0.634) 21.1%
8	0.36; ± 0.38 (0.134) 9.5%	−0.01; ± 0.43 (0.000) 10.3%	0.54; ± 0.32 (0.288) 18.7%	0.23; ± 0.41 (0.054) 21.6%	0.91; ± 0.09***(0.827) 4.3%	0.14; ± 0.42 (0.018) 16.8%
9	0.43; ± 0.43 (0.187) 10.1%	0.29; ± 0.47 (0.083) 10.8%	0.40; ± 0.44 (0.158) 23.0%	0.30; ± 0.46 (0.092) 23.9%	0.99; ± 0.01*** (0.975) 1.6%	0.57; ± 0.37 (0.320) 8.7%
10	0.27; ± 0.60 (0.075) 3.8%	0.33; ± 0.58 (0.107) 3.7%	0.34; ± 0.58 (0.118) 10.7%	0.17; ± 0.62 (0.027) 11.2%	0.82; ± 0.28*** (0.675) 2.2%	0.43; ± 0.55 (0.182) 14.8%
11	0.18; ± 0.37 (0.033) 2.2%	−0.02; ± 0.38 (0.001) 2.2%	−0.08; ± 0.38 (0.007) 8.8%	−0.15; ± 0.37 (0.021) 8.7%	0.21; ± 0.36 (0.046) 2.2%	0.73; ± 0.19** (0.529) 5.0%
12	−0.20; ± 0.92 (0.040) 2.5%	−0.29; ± 0.92 (0.085) 2.4%	0.15; ± 0.93 (0.021) 7.5%	0.44; ± 0.90 (0.190) 6.9%	−0.28; ± 0.92 (0.079) 2.40%	0.91; ± 0.56** (0.828) 4.3%
Mean	0.13; ± 0.29	0.17; ± 0.29	0.12; ± 0.29	0.17; ± 0.29	0.71; ± 0.15	0.57; ± 0.21

Min: minimun value; Max: maximun value; P: player; *r*: Pearson coefficient; R^2: coefficient of determination; Session RPEres: perceived cardiopulmonary training load; Session RPEmus: perceived muscular training load; TRIMP$_{MOD}$: modified training impulse; *V*: variation about regression.
$^*P < 0.05$, $^{**}P < 0.01$ and ***P < 0.001 significant individual correlations.

Table 5. Total correlations [±90% confident limit (CL)] in each bout between heart rate-based and perceived training load models during 4 versus 4 small-sided games.

Training load methods		Bout 1 *r*; ±CL (R^2) *V* (%)	Bout 2 *r*; ±CL (R^2) *V* (%)	Bout 3 *r*; ±CL (R^2) *V* (%)	Bout 4 *r*; ±CL (R^2) *V* (%)	**Total 4 × 4 SSG** *r*; ±CL (R^2) *V* (%)
Edwards	Session RPEres	0.15; ±0.29 (0.022) 11.3%	0.22; ±0.28 (0.048) 10.0%	0.26; ±0.28 (0.066) 10.5%	−0.17; ±0.29 (0.028) 11.2%	0.13; ±0.14 (0.017) 10.7%
	Session RPEmus	0.16; ±0.29 (0.026) 11.3%	0.09; ±0.29 (0.008) 10.2%	0.05; ±0.30 (0.003) 10.9%	−0.30; ±0.27 (0.091) 10.6%	0.03; ±0.15 (0.001) 10.8%
TRIMP$_{MOD}$	Session RPEres	0.18; ±0.29 (0.034) 29.9%	0.16; ±0.29 (0.027) 24.4%	0.24; ±0.28 (0.055) 23.7%	−0.15; ±0.29 (0.022) 24.8%	0.13; ±0.14 (0.018) 24.3%
	Session RPEmus	0.13; ±0.29 (0.017) 25.6%	0.05; ±0.30 (0.002) 24.7%	0.04; ±0.30 (0.002) 24.4%	−0.29; ±0.27 (0.082) 24.0%	0.02; ±0.15 (0.000) 24.6%
Edwards	TRIMP$_{MOD}$	0.94; ±0.04***(0.881) 3.9%	0.95; ±0.03***(0.903) 3.2%	0.98; ±0.03***(0.955) 2.3%	0.96; ±0.03***(0.930) 3.0%	0.96; ±0.01***(0.917) 3.1%
Session RPEres	Session RPEmus	0.74; ±0.14***(0.552) 23.5%	0.75; ±0.14***(0.565) 19.6%	0.78; ±0.12***(0.606) 16.2%	0.78; ±0.12***(0.613) 17.2%	0.78; ±0.06***(0.601) 18.5%

r: Pearson coefficient; R^2: coefficient of determination; Session RPEres: perceived cardiopulmonary training load; Session RPEmus: perceived muscular training load; TL: training load; SSG: small-sided games; TRIMP$_{MOD}$: modified training impulse; *V*: variation about regression.
$^{***}P < 0.001$ significant correlations.

characteristics (such as the intermittent high-intensity nature and the strength implications). Similar results were reported by Sampson, Fullagar, and Gabbett (2015) for rugby league players whose overall perceived effort was greater in the last bout than in the first bout in different types of small-sided games. Moreover, in only two out of eight types of small-sided games were differences in HR response (all of them in low HR zones) (Sampson et al., 2015). Methods based on the determination of cardiovascular capacities are insensitive to muscular fatigue, so they could not detect it. Similar results were reported by Los Arcos et al. (2014) in soccer players at the end of an official soccer match where session RPEmus was greater than session RPEres. Moreover, the mean session RPEmus match load in wheelchair basketball was higher (2.87%) than for session RPEres (Iturricastillo et al., 2016). Thus, our higher results for session RPEmus in the last bouts of the small-sided games suggest that at the end of small-sided games wheelchair basketball players have greater subjective perception of strain from their peripheral exercising muscles and joints than perceived tachycardia or breathing. This might be related to the size of muscle mass; hence, it would be informative to study how muscle mass or types of muscle fibre are related to subjective muscular perception during small-sided games. It would also be useful to determine fatigue at the muscle level in the upper limbs during game-based training tasks in wheelchair basketball. Session RPEmus could be an indicator that coaches should consider to quantify muscle fatigue in wheelchair basketball athletes.

The recent literature concerning the relationship between subjective and objective training load in different adapted sports is scarce (Iturricastillo et al., 2016; Paulson et al., 2015), while in able-bodied team sports these relationships are widely studied (Impellizzeri et al., 2004; Los Arcos et al., 2014; Scanlan et al., 2014). Individual correlations of our study between objective and subjective methods showed that there was a wide variety among all of them (*r* range = −0.88; ±0.10 to 0.90; ±0.08; range *V*% = 0.8–24.2%). These relationships are similar to those found by Campos-Vazquez et al. (2015) in soccer players, where a low relationship was observed between $TRIMP_{MOD}$ and RPE-based training load (range $r = 0.17$– 0.51; average $r = 0.35$). Similar but higher relationships were observed between Edwards' training load and RPE-based training load (range $r = 0.40$–0.67). In any case, there are many more papers on able-bodied sports supporting the relationship between both methods than denying that there is one (Impellizzeri et al., 2004; Manzi et al., 2010; Scanlan et al., 2014). Nevertheless, in wheelchair basketball, Iturricastillo et al. (2016) did not report a high relationship between HR-based match load and session RPE match load in all players in relation to injury type. Moreover, in the present study, the relationships between the HR-based training load group and the RPE-based training load group in each bout were trivial or small. Some studies have observed that the maximal HR in people with high-level SCI (lesion above T1–T5) could be impaired, such as lowered maximal HRs of about 100–135 beats per minute (Goosey-Tolfrey & Leicht, 2013). This could lead us to think that the lack of a relationship between RPE and HR could be due to the impairment itself. However, Paulson, Bishop, Leicht, and Goosey-Tolfrey (2013) showed very large correlations between physiological markers and subjective methods in eight male wheelchair-dependent participants with a cervical SCI at C5/6 (VO_2 and muscular RPE, $r = 0.91$; VO_2 and cardiopulmonary RPE, $r = 0.88$; VO_2 and overall RPE, $r = 0.90$). Other authors also found moderate to high relationships between objective and subjective methods in laboratory environments (Al-Rahamned & Eston, 2011; Paulson et al., 2013; Qi et al., 2015). In this sense, the intermittent high-intensity nature with a high anaerobic component and the characteristics of the small-sided games with muscle stress generated by stopping and going and changes of direction in the small-sided games, compared to the incremental testing of other studies, as well as the impairment of functional ability, could be the reason for the differences found. Therefore, the results revealed that the RPE-based training load methods could not explain the HR-based training load, so both methods might be measuring different internal loads in small-sided games. Thus, due to the disparity of affectation among wheelchair basketball players resulting in heterogeneity of IWBF classification scores, a different trend has been observed in each player according to the correlations between objective and subjective methods. For this reason, it might be recommendable for coaches to use both methods because both of them could provide relevant information.

This study analysed the training load of small-sided games by means of objective and subjective methods, as well as the correlations between them. However, the low sample precluded us from analysing the results with guarantees according to the impairment or functional class. For this reason, it could be very interesting to study if all players have similar training load and correlations attending objective and subjective methods in relation to impairment (i.e., SCI and non-SCI) and functional class (1–1.5, 2–2.5, 3–3.5 and 4–4.5) during different training tasks to determine the validity of objective and subjective methods in wheelchair basketball.

Conclusions

The training load in wheelchair basketball small-sided games was constant between bouts for HR-based methods and session RPEres, but not in session RPEmus. Therefore, even though the cardiovascular load seems to be constant between bouts, the session RPEmus could indicate muscle fatigue in this task. Thus, the coaches should add the quantification of the muscle load by session RPE as a complement of the HR monitoring in order to control its development during small-sided games.

The present results do not support the relationship between objective and subjective methods for quantifying high-intensity intermittent training tasks in wheelchair basketball players. Therefore, HR-based training load and RPE-based training load could provide different information, so the current training quantification should be considered independently. Nevertheless, the two methods might be complementary and one method could help us to understand the limitations of the other. Likewise, the individual correlations differ among players, possibly due to different impairment and IWBF classification scores, so further studies on the influence of injury correlations between HR and RPE methods are suggested.

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ORIGINAL ARTICLE

Physiological responses between players with and without spinal cord injury in wheelchair basketball small-sided games

A Iturricastillo, J Yanci, A Los Arcos and C Granados

Study Design: This is a comparative study between players with and without spinal cord injury (SCI) during a training task.
Objective: This study examined physiological responses in commonly used small-sided games (SSGs) in well-experienced wheelchair basketball (WB) players with SCI and without SCI (Non-SCI).
Setting: The study was conducted with a WB team in Vitoria-Gasteiz, Spain (2014).
Methods: The team was divided into an SCI group ($n=6$) and a Non-SCI group ($n=6$). Absolute and relative heart rate (HR) along with tympanic temperature and perceived exertion (RPE) were recorded for both groups.
Results: The two groups attained different absolute HR values for the same SSG. However, no significant differences were observed in relative HR between groups (%HRmean, %HRpeak and the percentage of the time spent in each HR zone: low, moderate, high and maximal) nor in tympanic temperature. Moreover, in relation to the bout evolution analysis (4 repetitions of 4 min), the Non-SCI group significantly increased ($P<0.05$) absolute HRmean and HRpeak during bouts, whereas the SCI group maintained them constant. Furthermore, the variations in the percentage of the time spent in each HR zone only were observed in the Non-SCI group.
Conclusion: In spite of the Non-SCI group attaining higher absolute HR values, the SCI and Non-SCI groups may have similar HR relative values during a specific WB training task. However, the SCI group reported significantly higher values in respiratory RPE in the last bout than the Non-SCI group for the same SSG.
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INTRODUCTION

Physiological demands in team sports have been analyzed in many studies during matches[1,2] and training sessions.[3,4] However, there is a lack of information about the time spent performing activities specific to wheelchair basketball (WB) and the physiological demands associated with this sport.[5] It is important to understand the physiological competitive sporting requirements,[6,7] as studied in able-bodied sports, to ensure that training reflects the demands of the sport. For this reason, heart rate (HR) monitors are mainly used to determine the exercise intensity of a training session or a competition in WB.[5,6,8,9] In addition, many studies are available on the metabolic and cardiovascular responses to wheelchair and arm ergometry,[10] but despite attempts to improve and optimize current training methods and sport-specific training,[5] more studies are required focused on the physiological demands of WB in specific training tasks.

Small-sided games (SSGs) are specific training tasks with the goal of reducing interactions and increasing the ratio of players' participation in decision-making but preserving basic variability properties from the game.[11] That is why, nowadays, SSGs are becoming increasingly popular in many team sports such as soccer,[3,4] rugby,[12] Australian football[13] and specially in basketball.[14,15] Essentially, SSGs represent a highly intense game, either specific or non-specific to the sport, which focuses on some aspect that the coach is attempting to improve.[16] The supposition that SSGs may simulate the physiological workloads and intensities commensurate with actual match play while also developing technical and tactical proficiency has led to its popularity as a training modality in the applied and scientific domain within recent years. Moreover, SSGs appear to replicate movement demands and require players to make decisions under pressure and in conditions of fatigue.[3] Nevertheless, only one study has analyzed the physiological responses in SSGs in WB.[17]

In many of the papers cited above, HR was a commonly used tool to describe physiological responses during matches[1,6,8] and training tasks.[17] However, HR was analyzed in absolute values instead of in relative values or according to the percentage of the time spent in each HR zone. Furthermore, none of these studies analyzed the differences between players with and without spinal cord injury (SCI). In addition, some studies cast doubt on the validity of HR measurements in athletes with SCI;[18,19] therefore, it could be interesting to analyze other ways of quantifying WB demands, such as rating of perceived exertion (RPE). RPE also forms a basis for prescribing an intensity of work paralleling that measured by physiological standards of HR, respiratory metabolic functions and lactate production.[18] For this reason, some authors[20] proposed differentiated RPE in comparison with the overall measure, to better explain the mechanisms of the subjective perceived exertion that can determine physical work. They distinguished three rates of RPE, focused on (i) 'local' or 'muscle' (RPEmus, that is, the feeling of strain in the working muscles),

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Table 1 Wheelchair basketball players' characteristics with (SCI) and without (Non-SCI) spinal cord injury

Player	*Group*	*Injury*	*Age (years)*	*IWBF classification*	*AIS grade*	*Injury time (years)*	*Training experience (years)*
P1	SCI	Spina Bifida (L1)	16	1	A	16	2
P2		Spinal cord injury (T1-T2)	36	1	A	34	20
P3		Spinal cord injury (incomplete (C5-C6)	35	3	C	30	18
P4		Spinal cord injury (T10)	30	3	A	2	1
P5		Spinal cord injury (T12-L3)	42	1	A	18	7
P6		Spinal cord injury (T3)	19	1	A	12	2
Sample (n=6)			30±10	—	—	18.67±11.78	8.33±8.54
P7	Non-SCI	Osteoarthritis congenital	40	4		40	21
P8		Hip labral tear	18	4		2	2
P9		Knee injury	25	4,5		5	2
P10		Viral disease (polio)	35	3,5		33	4
P11		Knee injury	41	4,5		9	9
P12		Amputation	35	4		28	15
Sample (n=6)			32±9	—		19.17±15.82	8.83±7.78

Abbreviations: AIS, ASIA Impairment Scale; IWBF, International Wheelchair Basketball Federation; SCI, spinal cord injury.
Results are in means±s.d.

(ii) 'central' or 'respiratory' (RPEres, that is, perceived tachycardia, tachypnea and even dyspnea) and (iii) 'overall' (RPE overall). Many studies involving people with disability have studied the differentiated RPE method,[21–23] using laboratory environments, but recently RPE (RPEres and RPEmus) has also been analyzed in WB matches.[7] Thus, it could be interesting to study the differentiated RPE method in intermittent high-intensity training tasks such as SSGs.

Therefore, the first aim of this study was to examine the physiological responses in commonly used basketball SSGs (4 vs 4) in well-experienced WB players with and without SCI. The second aim was to examine the development of the physiological variables during bouts and compare this evolution between groups.

METHODS

Participants

Twelve Spanish First Division WB players (age 30.8±9.5 years, sitting body height 82.9±9.1 cm, body mass 75.7±10.4 kg, HRmax 177.9±13.7 beats per min) participated in the study. The team was divided into two groups according to their injury type (Table 1). On the one hand, the group SCI (n=6, sitting body height 82.1±5.9 cm, body mass 72.4±8.8 kg, HRmax 173.5±15.3 beats per min) and on the other hand, the group Non-SCI (n=6, sitting body height 88.8±2.0 cm, body mass 78.9±11.5 kg, HRmax 182.3±11.5 beats per min). The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF) (from class 1=players with low functional capacity to class 4.5=players with high functional capacity). The inclusion criteria for the participants in the study were to have a valid license from the Spanish Federation of Sports for people with Physical Disabilities (FEDDF) and the certificate of disability that is necessary to belong to this federation. The Ethics Committee of the University of the Basque Country approved the study, and all participants provided written informed consent as outlined in the Declaration of Helsinki (2013).

Procedures

This study was conducted over five consecutive weeks (from November to December) during the competitive period with the team training twice per week (Tuesday and Thursday) and competing at weekends. The SSGs were part of the training sessions; hence, data were collected during the five consecutive Tuesdays, at the same time of the day (8–9 PM) and with at least 48 h rest between sessions. All the players took part in at least 70% of the bouts during five consecutive weeks. Thus, a total of 144 individual observations met all requirements and were included in the analysis. Moreover, the analysis took into account all the players who had completed the full training task (4×4 minutes). These bouts were presented as bouts 1 to 4. No strenuous exercises were performed within the 48 h immediately prior to the training sessions, and the researchers supervised the study at all times.

Data collection

Endurance test. To obtain the individual maximal HR (HRmax) of each player, all players completed a modified (10 m) Yo Yo intermittent recovery test level 1 (YYIR1 10 m)[17,24] 1 week before the SSGs were conducted. The YYIR1 10 m consists of repeated 2×10 m propels at a progressively increased speed controlled by audio bleeps from a pre-recorded source. This endurance test showed good reproducibility values (intraclass correlation coefficient= 0.83–0.94). All players were familiar with the field-testing procedures, as they were part of their usual fitness assessment program. During the test, HR was continuously monitored at 1-s intervals by telemetry (Polar Team Sport System, Polar Electro Oy, Kempele, Finland). The HRmax was determined from the highest value from the YYIR1.

Small-sided games (SSGs). The SSGs were performed on a basketball pitch (15×28 m) with a duration (4×4 min separated by 2 min of passive recovery) that was strictly controlled and has already been implemented by other researchers.[17] The game rules were the same as in a competitive match, with the exception of no free throws after a fault or time-outs allowed during the 4-min periods to avoid excessive stops. During the SSGs, two supporting subjects were located out of the play area with several balls for immediate availability to minimize any disruption of play, and thus the total duration of the SSGs represented the effective time of exercise. The teams were balanced with respect to their disability and according to the IWBF functional classification. Thus, players with SCI were intermixed with players without SCI to balance both groups. All the SSGs were preceded by a 10-min standardized warm-up (3 min of aerobic activity without the ball plus two linear sprints and two sprints with a change of direction). Players were not allowed to consume any type of drinks during the recovery periods, and all players received verbal encouragement from the coaches.

Heart rate during SSGs. HR was continuously monitored throughout the SSGs at 1-s intervals by telemetry (Polar Team Sport System, Polar Electro Oy). The HRmean and HRpeak were recorded in absolute values for all bouts of the SSGs. The HRmean expressed relative to each players' HRmax (%HRmax) for the entire 4×4 min SSG section of each training session was used for analysis.[14] In addition, four HR zones were established, and the percentage of the time spent in each zone during SSGs was calculated. The HR zones were defined as low (< 75% of HRmax), moderate (75–85% of HRmax), high (85–95% of HRmax) and maximal (> 95% of HRmax), according to previously established criteria in basketball.[1,15] The average value and standard deviation (s.d.) of each bout and group were used for the statistical analysis.

Table 2 Physiological responses between players with (SCI) and without (Non-SCI) spinal cord injury in WB 4 vs 4 small-sided games

	HR mean (beats per min)		*HR peak (beats per min)*		*Tympanic temperature (Celsius)*	
	SCI	*Non-SCI*	*SCI*	*Non-SCI*	*SCI*	*Non-SCI*
Bout 1	148.67±14.85	157.4±9.4	161.14±14.5*	170.9±8.03	36.87±0.51	36.75±0.71
Bout 2	150.17±14.86*	160.1±8.37[a]	163.1±15.75*	173.35±8.29[a]	36.89±0.63	36.77±0.74
Bout 3	150.5±11.93**	162.85±9.25[a,b]	161.5±13.38**	176.35±8.76[a]	36.83±0.68	36.9±0.63
Bout 4	150.1±13.86**	161.2±7.9[a]	161.83±13.53**	174.95±7.27[a]	36.96±0.66[a]	36.98±0.54[a,b]
Average	149.85±13.49***	160.39±8.95	161.85±13.88***	173.89±8.2	36.89±0.61	36.85±0.66

Abbreviations: HR, heart rate; SCI, spinal cord injury; WB, wheelchair basketball.
Values are means (± s.d.). *$P<0.05$, **$P<0.01$, ***$P<0.001$: significant difference between SCI and Non-SCI players.
[a]Significant difference ($P<0.05$) compared with bout 1
[b]Significant difference ($P<0.05$) compared with bout 2.

Tympanic temperature. A ThermoScan 5 IRT 4520 (Braun GmbH, Kronberg, Germany) was used to measure tympanic temperature. This is an infrared thermometer used in the predictive mode that can provide a measurement in seconds using an algorithm that extrapolates from the speed at which temperature changes as the thermometer warms up.[17,25] The data were recorded before the warm-up and immediately at the end of each 4-min bout by the same investigator on all occasions. The average value and s.d. of each bout and group were used for the statistical analysis.

Perceived effort. The 10-point scale proposed by Foster *et al.*[26] was used immediately after each SSG bout to determine how hard the exercise had been. Participants responded separately about the RPEres and the arm muscular RPEmus.[22–24] The same investigator recorded the data on all occasions, immediately after each 4-min bout. Each player completed the RPE scale without the presence of other players, and they could not see the values of other participants. Players were educated about the 10-point scale during a month before the data collection. Moreover, this scale was used in all the previous training sessions. The average value and s.d. of each bout and group were used for the statistical analysis.

Data analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS, Chicago, IL, USA). Standard statistical methods were used for the calculation of the mean and standard deviations. Data were screened for normality of distribution and homogeneity of variances using a Shapiro–Wilk normality test. Student's *t*-test for independent samples was used to determine the differences between groups in physiological responses in each bout independently, and analysis of variance repeated measures with an appropriate Bonferroni *post hoc* test was used to compare results among bouts in each group (SCI and Non-SCI) independently. In addition, the between-groups comparison from baseline to different bouts was calculated with a two-way mixed analysis of variance (bout × group). The $P<0.05$ criterion was used to establish statistical significance.

RESULTS

The absolute mean values of the physiological responses (HRmean, HRpeak and tympanic temperature) in a 4 vs 4 SSG are presented in Table 2. The Non-SCI group showed significantly higher values than the SCI group in HRmean and HRpeak but not in tympanic temperature. In addition, significant differences were observed between the first and the other bouts in HRmean and HRpeak in the Non-SCI group but not in the SCI group. Regarding tympanic temperature, the final bouts showed differences with respect to the first bouts in both groups. According to the two-way analysis of variance (bout × group), no variable showed statistical significance.

In relation to HRmean and HRpeak relative values (%HRmax), non-significant differences were observed between both groups (SCI vs Non-SCI), in all bouts. However, significant differences were observed in the Non-SCI group among bouts in HRmean (Figure 1a) and HRpeak (Figure 1b) but not in the SCI group.

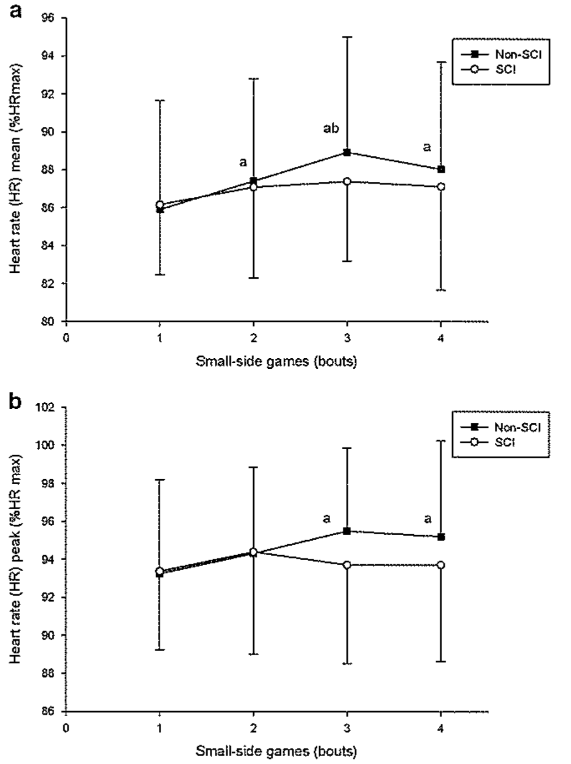

Figure 1 Relative values (%HRmax) bout to bout for players with SCI and without SCI (Non-SCI) in HRmean (a) and HRpeak (b). [a]Significant differences ($P<0.05$) compared with bout 1, [b]Significant differences ($P<0.05$) compared with bout 2.

Similarly, when intensity of exercise was expressed as a percentage of the time spent in different HR zones of HRmax, non-significant differences were observed between the SCI and the Non-SCI groups (Table 3). With respect to the differences among bouts in the Non-SCI group, the percentage of the time spent at 75–85% was significantly lower in the third and fourth bouts compared with the first one. In addition, significantly higher values were observed in the Non-SCI group in the second and third bouts compared with the first in the percentage of time spent at more than 95% of HRmax.

Table 3 **The percentage of the time spent in different heart rate (HR) zones between players with (SCI) and without (Non-SCI) spinal cord injury in wheelchair basketball 4 vs 4 small-sided games**

HR zones (%HRmax)	*Group*	*Bout 1*	*Bout 2*	*Bout 3*	*Bout 4*
Time at <75%	SCI	7.77±7.83	4.3±3.56	3.85±4.23	4.86±7.14
	Non-SCI	8.3±8.54	6.72±6.24	7.91±10.1	7.87±12.17
Time at 75–85%	SCI	29.82±27.08	35.89±29.54	28.98±26.05	27.32±26.22
	Non-SCI	35.95±28.13	27.64±25.5	20.18±16.89[a]	24.08±19.23[a]
Time at 85–95%	SCI	53.33±25.13	44.02±24.29	53.15±23.98	50.03±27.22
	Non-SCI	38.62±21.24	43.97±23.04	45.43±25.19	44.9±23.92
Time at >95%	SCI	9.65±16.35	15.83±24.63	14.06±20.22	17.74±24.45
	Non-SCI	15.74±25.25	21.25±31.60[a]	26.38±32.83[a]	23.1±27.02

Abbreviations: HR, heart rate; SCI, spinal cord injury. Values are means (±s.d.).
[a]Significant difference ($P<0.05$) compared with bout 1.

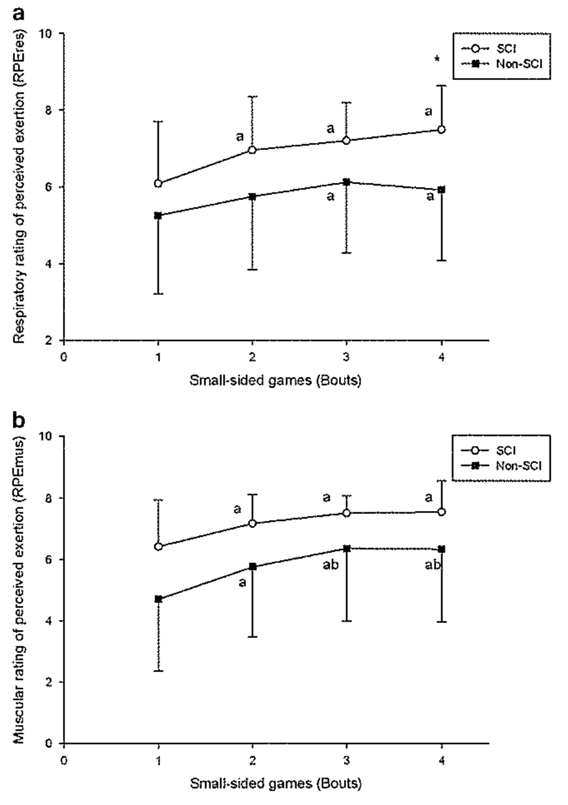

Figure 2 Respiratory (a) and muscular (b) perceived exertion bout to bout for players with SCI and without SCI (Non-SCI). *Significant differences ($P<0.05$) between SCI and Non-SCI. [a]Significant differences ($P<0.05$) compared with bout 1, [b]Significant differences ($P<0.05$) compared with bout 2.

The SCI group showed significantly higher values in RPEres in the last bout, but no significant differences were shown in RPEmus (Figure 2). Moreover, for the Non-SCI group in RPEres (Figure 2a), there were significantly higher values in the third and fourth bouts compared with the first one. Regarding RPEmus (Figure 2b), significantly higher values were observed in all bouts compared with the first one and in the third and fourth bouts compared with the second one for both groups. In relation to the SCI group, there were significant differences in all bouts compared with the first one.

DISCUSSION

In this study, we examined the HR responses, tympanic temperature and perceived exertion in 4 vs 4 SSG. Our results show that the players with SCI and without SCI may have similar HR relative values (%HRmean, %HRpeak, percentage of the time spent in different HR zones), although the Non-SCI group attained higher absolute HR (HRmean and HRpeak) values. Furthermore, no differences were observed between the two groups in relation to tympanic temperature. However, the players with SCI reported significantly higher values in RPEres in the last bout than the Non-SCI group for the same SSG.

Several studies have investigated the use of HR in able-bodied players as an indicator of exercise intensity;[1,14,15] however, there are few works in reference to wheelchair sports. Croft *et al.*[6] showed an average HRmean of 146±16 beats per min in wheelchair tennis and 163±11 beats per min in WB players during a match. Generally, our results are lower than those observed by Croft *et al.*[7] but almost the same or higher than those reported by others in the literature (range 128–151 beats per min, respectively)[5,8,9] for both groups (SCI and Non-SCI). The players with SCI attained a significantly lower HRmean (149.85±13.49 beats per min vs 160.39±8.95 beats per min) and HRpeak (161.85±13.88 beats per min vs 173.89±8.2 beats per min) than the Non-SCI group. Nevertheless, the s.d.s of HRmean and HRmax were higher than those observed in the Non-SCI group. In the case of SCI group, the results were higher than those reported by Goosey *et al.*[27] probably owing to the diversity in the lesion level of the SCI group of our study. It is well known that the work capacity of individuals with SCI is limited by loss of functional muscle mass and sympathetic control. Sympathetic nervous system impairment limits control of regional blood flow and cardiac output, and HRmax following cervical lesions may be reduced to 110–130 beats per min.[27] Thus, our results suggest that absolute HR values have to be interpreted with caution in players with SCI during high-intensity training tasks as they can lead to error.

Some authors reported absolute HR values in relation to a competitive WB match,[5,8,9] but only one study reported relative HRmean values (83.9±1.9%).[6] In this sense, both groups (SCI and Non-SCI) reached similar relative HRmean values (% HRmax) to those reported by Croft *et al.*[6] during WB matches (SCI=86.16±3.7%; Non-SCI=85.9±5.73%). Thus, to improve physical capacities, SSG could be useful because they represent highly intense games that simulate real play situations. Despite significant differences being observed in absolute values of HRmean and HRpeak between players with and without SCI during the 4 vs 4 SSG, there were none in the relative values (%HRmean, %HRpeak, percentage of the time spent in different HR zones). However, the SSG might be good training tasks for WB players because of the similarities with the physiological responses involved in a match. This could be an interesting finding as both groups may train at the same relative intensity, in spite of the difficulty of players with SCI to reach the HRmax. This means that when the values are expressed in relative values of their HRmax, the differences in the physiological demands of SSG for players with and without SCI disappeared. For this reason, relative HR could have more applicability for coaches or physical trainers to quantify the training load instead of absolute HR values.

The training for physiological responses during matches has been analyzed by objective (means of HR) and subjective (RPE) methods.[7,17] However, there is controversy in the literature about the relationship of HR and RPE for people with SCI.[18,19,23] Jacobs *et al.*[19] found a strong linear association between HR and VO_2 in participants with paraplegia but not between HR and RPE during functional neuromuscular stimulation-assisted ambulation. The results are consistent with those of Lewis *et al.*[18] who concluded that RPE is an invalid indicator of exercise intensity in participants with paraplegia. In contrast, evidence suggests that the RPE is effective in controlling moderate (50% VO_2peak) and vigorous (70% VO_2peak) intensities during hand cycling exercise in participants with SCI.[23] Considering that most studies were conducted in a laboratory setting at a given intensity or in incremental tests instead of field testing, it would be interesting to assess the HR–RPE relationship during the game itself[8] and specific training tasks. The most intriguing findings of the study were the contrasting tendencies of RPEres values with respect to relative HR values in players with SCI, thus supporting the controversy. However, for the Non-SCI group, there was a similar tendency in HR and RPE, as they showed a similar rising trend in RPE values when increasing absolute and relative HR during bouts. In this sense, the intermittent high-intensity nature and characteristics of the SSG, as well as physiological impairments or diverse functional ability, could be the reason for the contrasting tendencies between HR and RPE values. More studies are therefore necessary to analyze the objective and subjective values in players with SCI during high-intensity intermittent training tasks because both methods might be measuring a different internal load during SSG.

It is well accepted that people with SCI have a lesser ability to regulate core temperature because of impaired vasomotor and sudomotor activity below their level of injury.[28] In this case, non-significant differences were observed between the SCI and Non-SCI groups in 4 vs 4 full court SSG, regarding tympanic temperature. This might be due to the short duration of the exercise, despite it being at high intensity. Nevertheless, in both groups, significantly higher values were observed between the first and the last bout. Furthermore, the Non-SCI group showed significantly higher values in the last bout with respect to the second bout. Core temperature has an important role in physical performance,[29] given that it could be adversely affected by the increase in core temperature at rest and during exercise.[30] If adequate fluid intake is not maintained, the players' thermoregulatory capacity is diminished.[31] In individuals with SCI, this situation may become a potential physiological problem, as a lack of sympathetic vasomotor adjustment and reduced sweating capacity below the lesion level may hamper appropriate blood redistribution and limit cooling efficiency.[32]

Practical applications

The main conclusion of this study is that players with and without SCI may have similar HR relative values, although the Non-SCI group attained higher absolute HR values. Therefore, it would be interesting to analyze not only the absolute values of HR but the relative values during WB to quantify the intensity and the internal load of SCI players. For future studies, it would be interesting to compare the relative HR values between SCI and Non-SCI players in different training tasks or matches to determine whether the training or match intensity is the same for every player or not. On the other hand, the players with SCI reported significantly higher values in respiratory RPE in the last bout than the Non-SCI group for the same SSG. Thus, by means of SSG, we might be able to develop anaerobic capacity in a similar manner both in the Non-SCI group and the SCI group. However, the contrasting tendencies between HR and RPE values lead us to reflect about the need for more studies in players with SCI as both methods (HR and RPE) might be measuring a different internal load during SSG.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ORIGINAL INVESTIGATION

Quantifying Wheelchair Basketball Match Load: A Comparison of Heart-Rate and Perceived-Exertion Methods

Aitor Iturricastillo, Javier Yanci, Cristina Granados, and Victoria Goosey-Tolfrey

Purpose: To describe the objective and subjective match load (ML) of wheelchair basketball (WB) and determine the relationship between session heart-rate (HR) -based ML and rating-of-perceived-exertion (RPE) -based ML methods. ***Methods:*** HR-based measurements of ML included Edwards ML and Stagno training impulses ($TRIMP_{MOD}$), while RPE-based ML measurements included respiratory (sRPEres) and muscular (sRPEmus). Data were collected from 10 WB players during a whole competitive season. ***Results:*** Edwards ML and $TRIMP_{MOD}$ averaged across 16 matches were 255.3 ± 66.3 and 167.9 ± 67.1 AU, respectively. In contrast, sRPEres ML and sRPEmus ML were found to be higher (521.9 ± 188.7 and 536.9 ± 185.8 AU, respectively). Moderate correlations (r = .629–.648, P < .001) between Edwards ML and RPE-based ML methods were found. Moreover, similar significant correlations were also shown between the $TRIMP_{MOD}$ and RPE-based ML methods (r = .627–.668, P < .001). That said, only ≥40% of variance in HR-based ML was explained by RPE-based ML, which could be explained by the heterogeneity of physical-impairment type. ***Conclusion:*** RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players.

Keywords: match activity, RPE, TRIMP, training load, Paralympic

To evaluate the success of training, coaches need to systematically monitor athletes' internal training load (TL).[1] Understanding TLs will allow coaches to monitor the effectiveness of training and competitive stimuli in provision of a successive training plan.[2] Consequently, TL has been analyzed in many able-bodied team sports during training[2–6] and competitive match play.[7–9] Monitoring TL or match load (ML) helps the coach individualize training with respect to simulating game play via certain drills in training or, indeed, individualizing the physical load due to the player's positional requirements. Thus, methods based on the analysis of heart rate (HR) as the measurement of Banister training impulses,[10] Edwards method,[11] or modified Stagno training impulses ($TRIMP_{MOD}$)[12] have been used to quantify TL in many sports such as soccer,[3,9,13–15] Australian football,[16,17] and water polo.[2]

Evidently, not only has HR analysis been used to quantify TL, but also over the last decade researchers are combining other objective measures of TL such as athlete rating of perceived exertion (RPE). For example, several authors have successfully verified the quantification of TL or ML by multiplying an athlete's RPE for the total duration (min) of the training or match play in team sports.[2,5,15,17,18] Extending this further, recent work has differentiated between the subjective measure of RPE and RPE as scores relating to overall or respiratory RPE (RPEres) and muscular RPE (RPEmus).[14,19] This may be pertinent when working in adapted sports such as wheelchair basketball (WB), since wheelchair propulsion involves exercise of the upper extremities, which are prone to peripheral fatigue.[20]

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With the increasing professionalism of Paralympic sport, it is surprising to see that little is known about the competitive conditions that are faced by wheelchair sportspersons.[21–25] There is a paucity of data quantifying the physiological responses during WB game play[21,26–28] or mobility performance via tracking distances covered, like those reported in the wheelchair sports of tennis and rugby.[23,25] To our knowledge there are no studies examining the HR-based method of quantifying TL in wheelchair sports despite our anecdotal observations that many coaches have access to these methods (eg, HR monitors). An alternative low-cost and practical strategy to quantify ML is session RPE,[18] which has been extensively shown as a valid and reliable load-monitoring tool in many able-bodied team sports.[15,18] Moreover, monitoring internal loads using session RPE and hormonal responses has been identified in simulations and official basketball competitive outputs[29] but yet to be proven a viable option to consider in wheelchair sports. Because the disability type influences the HR response to wheelchair sport,[30] it may be necessary to meet ML by HR-based method and RPE-based methods specifically in WB players.

Therefore, the purpose of this study was to describe the objective and subjective ML of WB game play and to investigate the relationship between HR- and RPE-based ML methods across a competitive WB season.

Methods

Participants

Ten Spanish First Division male WB players (age 34 ± 8 y, time since injury 24 ± 12 y, WB training experience 11 ± 7 y, and 4 to 6 training h/wk) volunteered to participate in the study. The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (Table 1). This study was approved by the institutional research ethics committee, and all participants provided written informed consent as outlined in the Declaration of Helsinki (2013).

Table 1 Wheelchair Basketball Player Characteristics

Player	Physical impairment	IWBF classification	Age (y)	Injury time (y)	Training experience (y)	Modified YYIR1 (beats/min)	Match (beats/min)
1	SCI (T12–L3)	1	42	18	7	191	196
2	Spina bífida (L1)	1	16	16	2	180	195
3	SCI (T1–T2)	1	36	34	20	154	160
4	Viral disease (polio)	2	35	33	4	198	204
5	SCI (incomplete C5–C6)	3	35	30	18	169	182
6	Viral disease (polio)	3.5	33	31	14	176	189
7	Congenital osteoarthritis	4	40	40	21	179	183
8	Double below-knee amputation	4	35	28	15	185	201
9	Knee injury	4.5	41	9	9	169	187
10	Knee injury	4.5	25	5	2	182	184
Sample mean ± SD (n = 10)		—	34 ± 8	24 ± 12	11 ± 7	178 ± 12	188 ± 13

Abbreviations: IWBF, International Wheelchair Basketball Federation; YYIR1, Yo-Yo Intermittent Recovery Test Level 1; SCI, spinal-cord injury.

Data-Collection Period

Data were collected over a 6-month competitive season during the squad's buildup to end-of-season game play in March. During this period players undertook 2 training sessions and 1 match per week. Data from 16 matches were collected from the competitive match play as HR- and RPE-based ML. All players completed at least 4 matches, so a minimum of 4 full observations were considered for the analysis. A total of 111 individual observations met all requirements and were included in the analysis.

Endurance Test

To obtain individual maximal HR (HRmax), a 10-m Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) as described by Yanci et al[31] was completed by all players 1 week before the competition period. This endurance test has been verified using WB players and has shown good reproducibility (ICC = .83–.94). All players were familiar with this test as it had been part of their usual fitness-assessment program. During the test, HR was continuously monitored at 1-second intervals by telemetry (Polar Team Sport System, Polar Electro Oy, Kempele, Finland). HRmax was determined from the highest value from either the YYIR1 or game play.

Determination of ML

The ML for each player was determined during each match by 4 different methods: Edwards ML,[11] $TRIMP_{MOD}$,[12] and other 2 RPE-based methods described later. HR was continuously monitored throughout the matches at 1-second intervals by telemetry (Polar Team Sport System, Polar Electro Oy, Kempele, Finland). For ease of data collection, the whole match time (the rest time and substitution time on the bench) was reported for the analysis. Collection was only paused during periods of extended stoppage (time-outs, equipment calls) throughout the match since WB players also remain active during the stopped game clock.

Edwards ML Method. ML calculation was performed as proposed by Edwards.[11] In brief, this included the total volume of match intensity, which considers 5 zones of different intensity. The calculation was performed for each session by multiplying the accumulated duration in each HR zone (min) for a value assigned to each intensity zone (90–100% HRmax = 5, 80–90% HRmax = 4, 70–80% HRmax = 3, 60–70% HRmax = 2, 50–60% HRmax = 1) and summing the results.[5,6]

$TRIMP_{MOD}$ Method. Calculations of TRIMP were also performed as described by Stagno et al.[12] For this calculation, the ML is determined by calculating the result of multiplying the match duration (min) in each of the current zones for the weighting factor for each zone (93–100% HRmax = 5.16, 86–92% HRmax = 3.61, 79–85% HRmax = 2.54, 72–78% HRmax = 1.71, 65–71% HRmax = 1.25) and summing the results.[3,12]

RPE-Based Methods. RPE using the 0- to 10-point scale[18] was recalled by each player at the end of each match. Participants differentiated between the overall or respiratory RPE (RPEres) and the arm-muscle RPE (RPEmus) as previously noted for wheelchair ambulation.[20,32] In accordance with the work of Foster et al,[18] to estimate the RPE-derived ML (sRPEres ML and sRPEmus ML), the RPEres and RPEmus values were multiplied by the total duration of the match (min). Players were fully familiar with the 0- to 10-point scale before the data collection since these methods had been used previously during the preseason.

Data Analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS, Chicago, IL, USA). Standard statistical methods were used for the calculation of means and standard deviations. Data were screened for normality of distribution. The relationships between HR- and RPE-based ML scores were assessed using Pearson product–moment correlation (r), as well as the coefficient of determination (R^2). The $P < .05$ criterion was used to establish statistical significance.

Results

As shown in Table 1, game play elicited greater mean HRmax values than that found in the YYIR1 (188 ± 13 vs 178 ± 12 beats/min, respectively, $P < .001$), so thereafter these HR values obtained from game play were used for the following calculations.

The ML of each match across the 16 matches is shown in Figure 1. The mean value using the method of Edwards ML was

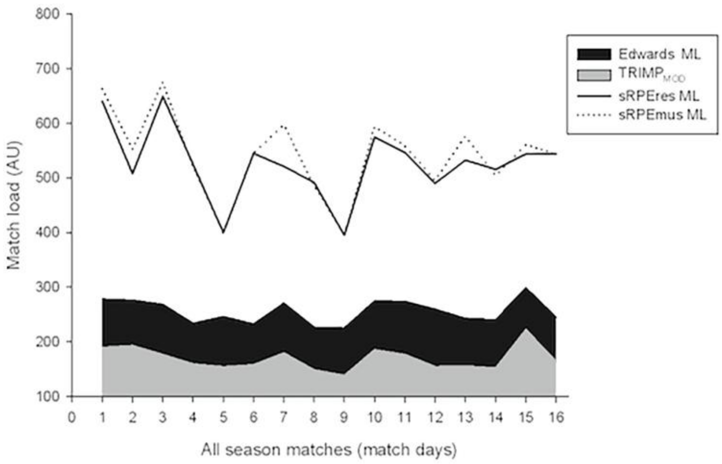

Figure 1 — Edwards match load (Edwards ML), Stagno modified TRIMP ($TRIMP_{MOD}$), and match load (ML) based on respiratory and muscular session rating of perceived exertion (sRPEres ML and sRPEmus ML) for the whole team during the 16 wheelchair basketball matches. Abbreviation: AU, arbitrary units.

255.3 ± 66.3 AU and for $TRIMP_{MOD}$ was 167.9 ± 67.1 AU. Moreover, the means for subjective ML were 521.9 ± 188.7 AU and 536.9 ± 185.8 AU for sRPEres and sRPEmus, respectively.

According to the whole team's values, moderate correlations were found between RPE-based ML methods and Edwards ML (sRPEres ML, $r = .629$, $R^2 = .40$, $P < .001$, and sRPEmus ML, $r = .648$, $R^2 = .42$, $P < .001$) and $TRIMP_{MOD}$ (sRPEres ML, $r = .627$, $R^2 = .39$, $P < .001$, and sRPEmus ML, $r = .668$, $R^2 = .45$, $P < .001$) methods (Figure 2). Nevertheless, there were not significant correlations in all individuals between HR- and RPE-based ML methods (Table 2).

The correlations of objective and subjective methods with the mean values of each match were moderate ($r = .511–.609$, $R^2 = .261–.371$, $P < .05$). As was expected, high correlations were observed between Edwards ML and $TRIMP_{MOD}$ methods ($r = .959$, $R^2 = .920$, $P < .001$) and sRPEres ML and sRPEmus ML methods ($r = .919$, $R^2 = .842$, $P < .001$).

Discussion

The RPE-based TL method has been widely correlated with stress responses[29] and the HR-based TL score in many able-bodied sports.[2,15,18,33] However, to date it is unknown how transferable these methods are to the sport of WB, which involves wheelchair propulsion of persons with a physical impairment. Thus, the current study described the ML and investigated the HR- and RPE-based ML methods in WB players during a whole competitive basketball season. The results revealed that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players, with some cautionary attention because RPE-based ML should not be seen as a substitute for HR-based ML. In terms of the individual correlations between subjective and objective methods, there were not a significant relation in all the players, so both the large heterogeneity of physical impairment types and a reduced number of cases for each individual could condition the relation between both methods.

The current study found that when using the HR-based method adopted by Edwards the ML values were higher than when using the $TRIMP_{MOD}$ method (255.3 ± 66.3 AU vs 167.9 ± 67.1 AU). That said, both these values were found to be lower than those reported for nondisabled basketball practices and/or games (652 ± 59 AU, Edwards ML).[18] Moreover, the subjective methods for quantifying ML were found to be similar between methods for the WB players (521.9 ± 188.7 AU vs 536.9 ± 185.8 AU for sRPEres and sRPEmus, respectively). Similar to this, Foster et al[18] found higher sRPE values (744 ± 84 AU) during basketball games. Obviously, this comparison must be done with caution since a complete spinal-cord injury results in paralysis of the voluntary muscles below the level of lesion.[34] Consequently, a reduced muscle mass is available for exercise. In conjunction with factors such as reduced sympathetic nervous system innervation and cardiovascular function, maximal exercise capacity is lower than in able-bodied individuals.[34] The differences between our findings and those reported by Foster et al[18] were 29.9% for sPREres and 27.8% for sRPEmus in AU. These lower values could be due to the muscle-mass differences between modalities and the different consequences of a spinal-cord injury as previously mentioned.

The relationship between objective and subjective methods has been widely analyzed in training tasks[5,6] and competition[8,9] in team sports. In our study, the relationship between RPE- and HR-based ML methods was moderate ($r = .627$ for sRPEres ML and $r = .668$ for sRPEmus ML). Such findings are consistent with previous studies involving other team sports.[8,9] In the same way, very high correlations were found between sRPEres ML and sRPEmus ML ($r = .919$). The relationship between HR- and RPE-based ML in the studies previously cited was moderate between objective and subjective methods ($r = .60–.61$; $P < .05$) in soccer players and soccer referees.[8,9] As Impellizerri et al,[15] we suggest that the RPE-based ML score cannot yet replace the HR-based ML methods as a valid measure of exercise intensity, as sRPEres ML and sRPEmus ML could only explain 40% of the variation measured by HR, or even less in some cases. This could be due to the intermittent-exercise nature of team sports (aerobic and anaerobic sources) reducing the grade of correlations between RPE-based TL and Edwards HR-based TL method. In addition, Bridge et al[7] reported that under certain training and competitive conditions, athletes tend to report lower RPE-based TL than their actual HR responses. Other authors

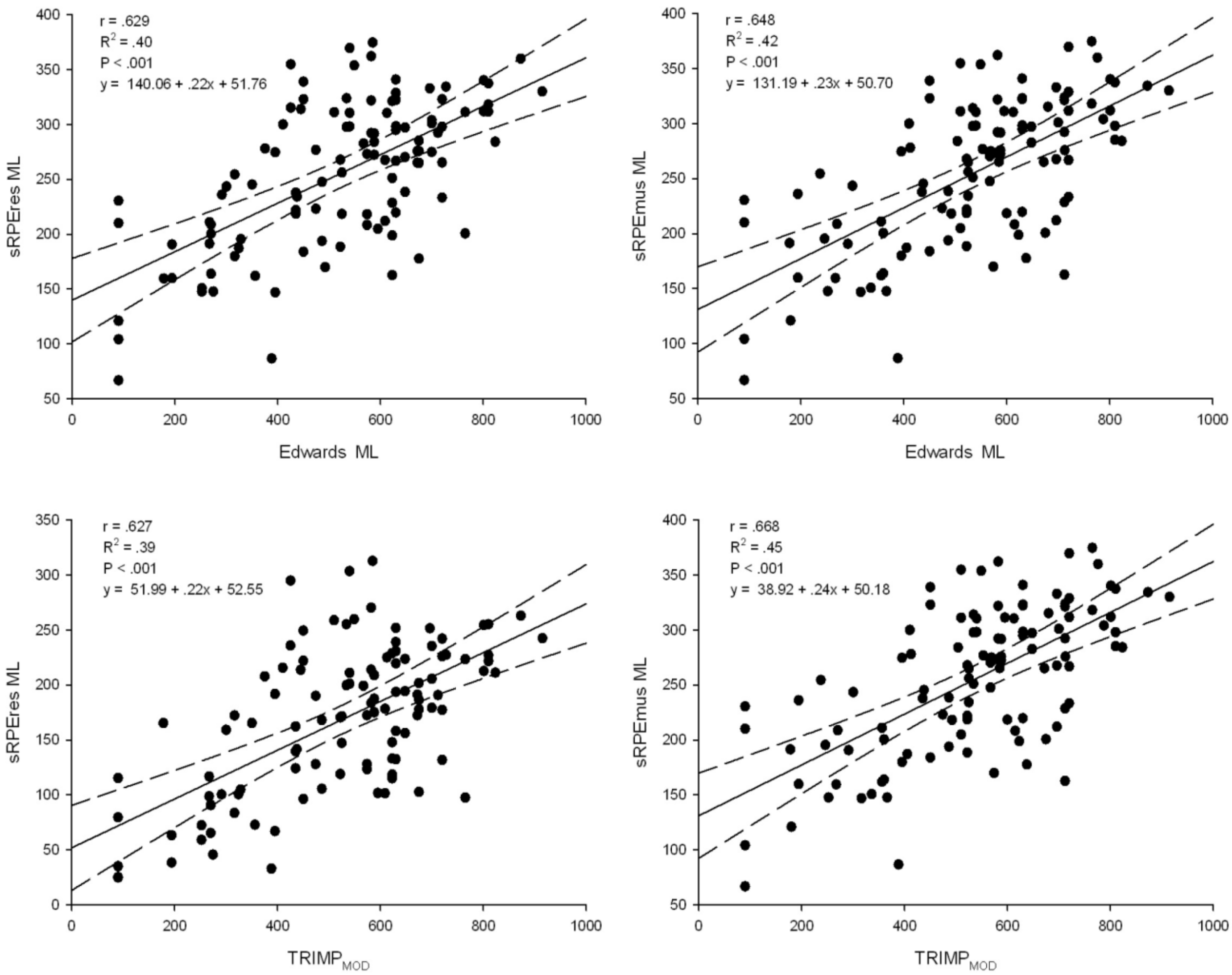

Figure 2 — Correlation between overall heart-rate-based match load (ML) (Edwards ML and $TRIMP_{MOD}$) and sRPE-based match load (sRPEres ML and sRPEmus ML) of 111 observations. Confidence interval (CI) 90%. Abbreviations: $TRIMP_{MOD}$, Stagno modified training impulse; sRPEres = respiratory session rating of perceived exertion; sRPEmus = muscular session rating of perceived exertion.

such as Lupo et al[2] inferred that the game may tend to make the RPE values less reliable because of a high grade of involvement and good time during the practice, thus underestimating their efforts. For this reason, Borresen and Lambert[33] attempted to identify characteristics that may explain the variance not accounted for in the relationship between the objective (HR-based) and subjective (RPE-based) methods of quantifying TL. Rhodes et al[23] clearly showed the intermittent nature of match play during wheelchair rugby, which is a wheelchair sport similar to WB. Of interest were the noted differences in high-intensity activities among the functional classification during a wheelchair rugby match. This could be attributed to the superior trunk function associated with higher-classification groups. For this reason, similar situations may come about in WB, so for the athletes who spent a greater percentage of their training time doing high-intensity exercise, the objective (HR-based) equations may overestimate TL compared with the subjective (RPE-based) method.[33]

According to the individual correlations, there were significant correlations between HR- and RPE-based ML in most of the cases; nevertheless, no correlations were found in several cases concerning different disabilities. Lupo et al[2] reported high individual correlations (r = .76–.98, R^2 = .58–.97, P < .05) in water polo training tasks. Impellizzeri et al[15] found moderate correlations (r = .50–.85 for individuals) between TLs calculated using the RPE-based TL and the HR-based TL for members of a club soccer team. These individual high correlations also were observed in basketball training tasks between Edwards TL and RPE-based TL methods (r = .69–.85 for individuals).[5] In the study of Scanlan et al[6] the sRPE TL model was significantly correlated with the Banister training impulse model (r = .80, P < .05) and Edwards TL model (r = .89, P < .05) across all sessions. Generally, our results are lower than those observed by those authors.[2,5,6,15] However, in this study, as previously mentioned, not all of WB players obtained significant correlations.

In the recent literature regarding different disabilities, some studies corroborated the relationship between RPE and other physiological markers in laboratory environments, but not in a real game situation or in training sessions in WB.[32,35–37] Paulson et al[32] reported

Table 2 Individual Correlations Between Match Load Based on Heart Rate (Edwards and $TRIMP_{MOD}$) and on Respiratory and Muscular Session Rating of Perceived Exertion (sRPEres and sRPEmus)

	Edwards Match Load						$TRIMP_{MOD}$ Match Load					
	sRPEres			sRPEmus			sRPEres			sRPEmus		
Player	*r*	95% CI	R^2	*r*	95% CI	R^2	*r*	95% CI	R^2	*r*	95% CI	R^2
1	.63*	0.15–1.12	.40	.69**	0.24–1.15	.48	.66*	0.18–0.13	.43	.69**	0.23–1.15	.47
2	.65**	0.20–1.11	.43	.59*	0.11–1.08	.35	.78**	0.40–1.15	.60	.70**	0.27–1.13	.49
3	.48	–0.40 to 1.36	.23	.69	–0.03 to 1.41	.48	.36	–0.57 to 1.30	.13	.66	–0.09 to 1.41	.43
4	.92	–0.24 to 2.09	.85	.92	–0.24 to 2.09	.85	.98*	0.31–1.64	.95	.98*	0.31–1.64	.95
5	.71**	0.21–1.21	.50	.72**	0.22–1.21	.51	.68*	0.14–1.24	.47	.68*	0.13–1.24	.46
6	.47	–0.15 to 1.09	.22	.41	–0.23 to 1.05	.17	.61*	0.05–1.17	.37	.55	–0.04 to 1.14	.30
7	.62*	0.02–1.04	.38	.67*	0.01–1.03	.45	.67*	0.01–1.03	.44	.64*	0.10–1.07	.41
8	.71**	0.26–1.15	.50	.52	–0.01 to 1.06	.27	.61*	0.11–1.11	.37	.46	–0.09 to 1.02	.22
9	.53*	0.06–1.17	.28	.52*	0.15–1.19	.28	.52*	0.14–1.19	.27	.59*	0.10–1.18	.35
10	.89*	0.07–1.72	.80	.85	–0.13 to 1.83	.72	.85	–0.13 to 1.82	.72	.82	–0.25 to 1.88	.67
Minimum	.47	—	.22	.41	—	.17	.364	—	.13	.46	—	.22
Maximum	.92	—	.85	.92	—	.85	.976	—	.95	.98	—	.95
Mean ± SD	.66 ± .16		.46 ± .22	.66 ± .15		.46 ± .21	.67 ± .17		.48 ± .23	.68 ± .14		.48 ± .21

Abbreviations: $TRIMP_{MOD}$, Stagno modified training impulse; CI, confidence interval.

*$P < .05$, **$P < .01$: significant correlations between methods based on rating of perceived exertion and on heart rate.

strong linear relationships between oxygen uptake and local (r = .91), central (r = .88), and overall RPE (r = .90) in 8 male wheelchair-dependent participants with a cervical spinal-cord injury at C5–C6. Although those laboratory studies support the use of RPE as a tool to self-regulate the intensity of wheelchair-propelled exercise, more studies are necessary in an intermittent-exercise situation in WB to determine the validity of a subjective method to quantify the ML. As we explained herein, even if the whole team obtained moderate correlation between RPE- and HR-based ML methods, not all WB players obtained significant correlations. For this reason, it would be interesting to pursue this issue and determine which injury type correlates better. Thus, we could improve current training methods and optimize sport-specific training.

Conclusions

Our results suggest that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players. This method is a cost-effective and a practical tool that any coach could administer as long as he or she were confident that the players had been familiarized with the 0-to-10 RPE scale. That said, since only ~40% of variance in HR-based ML was explained by RPE-based ML, although RPE could be considered a proxy measure of ML it should not be seen as a substitute for HR. This may be explained by the sample recruited, since large heterogeneity of physical-impairment types existed, which is typical of the makeup of a WB team. This is likely to have influenced the subjective methods of quantifying ML. This warrants further attention, and future studies should explore whether there are different RPE responses of players with a spinal-cord injury compared with those with a nonspinal injury so that match play and training quantification can be accurately reported via subjective measures.

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10.4. LAUGARREN ERANSKINA: *Estantzia*

centro de investigación del deporte
Universidad Miguel Hernández de Elche

D. EDUARDO CERVELLÓ GIMENO, profesor titular de la Universidad Miguel Hernández y Director del Centro de Investigación del Deporte; y D. RAUL REINA VAÍLLO, profesor titular de la Universidad Miguel Hernández, investigador del Centro de Investigación del deporte, y jefe de clasificación (HoC) de la *International Federation Cerebral Palsy Football* (IFCPF)

CERTIFICAN QUE:

AITOR ITURRICASTILLO URTEAGA ha realizado una Estancia de Investigación en el Centro de Investigación del Deporte en el periodo comprendido entre el 1 de junio y el 6 de agosto de 2016 en la temática sobre análisis del rendimiento y clasificación basada en evidencias en deporte paralímpico. Además, éste ha formado parte del equipo de investigación (*Research Staff*) de la International Federation of Cerebral Palsy Football (IFCPF) llevando a cabo valoraciones de la condición física de los jugadores y registrando la actividad (*match analysis*) de los jugadores durante el desarrollo de los partidos del *World Championship Qualification Tournament* disputado en Vejen (Dinamarca) del 29 de Julio al 6 Agosto de 2016.

Y para que conste a los efectos oportunos, se expido el presente certificado a petición del interesado en Elche, a 15 Septiembre de 2016.

Dr. Eduardo Cervelló Gimeno
Director CID

Dr. Raul Reina Vaíllo
Investigador CIF y IFCPF HoC

UNIVERSITAS Miguel Hernández

INTERNATIONAL FEDERATION OF CP FOOTBALL