ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2016;97:1938-44

ORIGINAL RESEARCH

Exercise Intensity During Power Wheelchair Soccer

J.P. Barfield, DA,[a] Laura Newsome, PhD,[a] Laurie A. Malone, PhD[b]

From the [a]Department of Health and Human Performance, Radford University, Radford, VA; and [b]University of Alabama-Birmingham/Lakeshore Research Collaborative, Birmingham, AL.

Abstract

Objective: To determine exercise intensity during power wheelchair soccer among a sample of persons with mobility impairments.

Design: Cross-sectional descriptive.

Setting: On-site training facilities of multiple power wheelchair soccer teams.

Participants: Participants with severe mobility impairments (N = 30) (mean ± SD, age: 29.40±15.51y, body mass index: 24.11±6.47kg/m^2, power soccer experience: 7.91±3.93y, disability sport experience: 12.44±9.73y) were recruited from multiple power wheelchair soccer teams.

Interventions: Portable metabolic carts were used to collect oxygen consumption ($\dot{V}O_2$) data during resting and game play conditions.

Main Outcome Measures: Average $\dot{V}O_2$ (expressed in metabolic equivalent tasks [METs]) during resting and game play conditions and rating of perceived exertion for game play.

Results: $\dot{V}O_2$ increased from 1.35±0.47 METs at rest to 1.81±0.65 METs during game play. This 34% increase in exercise intensity was significant ($P<.01$) and supported by a mean perceived exertion score of approximately 13 (somewhat hard).

Conclusions: Although not able to sustain an intensity associated with reduced secondary disease risk (ie, 3 METs), the documented light-intensity exercise in the current study surpassed an intensity threshold associated with improved functional capacity and performance of daily living activities (ie, 1.5 METs).

Archives of Physical Medicine and Rehabilitation 2016;97:1938-44

Since the classic studies of Blair and Brodney[1] and Paffenbarger et al,[2] research has consistently shown the relationship between activity-based energy expenditure and reduced risk for chronic mortality and morbidity. Although this behavioral risk reduction balance is important to the general population, it becomes even more essential to persons with disabilities. Disability refers to an impairment that limits 1 or more activities of daily living. Unfortunately, persons with disabilities, in particular physical disabilities, are less likely to engage in healthy physical activity behavior compared with persons without disabilities.[3-5] As a result, this population not only faces morbidity concerns with their primary disability, but also secondary disease risk (eg, coronary artery disease and obesity) becomes profound.[6,7]

Fortunately, exercise and physical activity behavior have multiple beneficial outcomes for persons with physical disabilities. Similar to the general population, regular physical activity among persons with physical disabilities results in improved fitness,[8-11] improved lipid profiles,[9,10] enhanced vascular function,[9] and reduced chronic disease risk.[6,9] For these benefits to occur, the activity or exercise has to be a regular part of one's lifestyle and must be sustained at a specific intensity. The intensity threshold for the aforementioned health benefits is considered moderate-intensity exercise and can be quantified as 3 metabolic equivalent tasks (METs) or, stated differently, an exercise intensity that is 3 times the energy expenditure at rest.[12,13]

However, persons with physical disabilities, especially those with mobility impairments, are more likely to engage in light-intensity exercise, an effort that falls below the 3-MET threshold.[14,15] Light-intensity exercise has important benefits to persons with mobility impairments, including maintenance of functional capacity or the ability to complete everyday tasks.[12,13,16] For example, a lifestyle that includes light-intensity physical activity results in improved wheelchair mobility,[17,18] improved self-care skills,[18] enhanced self-concept,[11] and enhanced life satisfaction.[19] Although there is debate as to the exact intensity range and minimum threshold for a behavior to be considered light-intensity exercise, 1.5 METs is the criteria most often reported as the

Supported by a Seed Grant from the Sponsored Research and Grants Management Department of Radford University.

Disclosures: none.

0003-9993/16/$36 - see front matter © 2016 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2016.05.012

threshold that distinguishes light-intensity exercise from sedentary behavior (<1.5 METs).[20,21] This threshold is an important marker for persons with mobility impairments because the ability to engage in light-intensity exercise above 1.5 METs reduces functional decline.[22]

Wheelchair sport as exercise

Increased popularity of disability sport is now exposing more persons with mobility impairments, especially manual wheelchair users, to the protective effects and functional benefits of regular physical activity. Disability sport is a meaningful rehabilitation and postrehabilitation physical activity option and, unlike able-bodied sport, provides greater participation opportunities as people age.[8,23-26] Sport can be an effective exercise mode because it has the ability to improve both functional capacity and quality of life.[27-29] Functional capacity, or the ability to do work such as activities of daily living, is unquestionably enhanced through sport-based fitness improvement.[30] Additionally, quality of life gains are realized through a variety of mechanisms including enhanced personal relationships,[29,31] improved self-care skills, and acceptance of disability.[18,23,25,32-35] However, the exercise stimulus or demand varies with each sport, yielding different exercise intensities during game play that, in turn, yield varied chronic adaptations. To identify the potential health or functional outcomes of regular participation in any sport, it is essential to determine the activity-based exercise intensity for each.

Although there are not an extensive amount of exercise intensity studies on manual wheelchair sport, the initial efforts show sustained moderate-intensity exercise across a variety of competitive sports. Wheelchair basketball has 1 of the highest activity-based energy demands, resulting in intensities between 4 and 8 METs.[36-40] Wheelchair tennis, despite the individual nature of the sport, does not pose as high a demand. However, sustained intensities of 3.5−6 METs have been consistently reported.[37,41] Energy expenditure has also been examined in wheelchair rugby, and because of the reduced active muscle mass in these athletes (ie, players with tetraplegia), sustained energy expenditure appears to be close to the moderate-intensity threshold, namely 3 METs.[36] Interestingly, exercise intensity sustained during certain active video games appears to be consistent with some manual wheelchair sports. Sustained intensities of 3−5 METs have been shown across games such as Wii boxing,[a] Wii tennis,[a] and Dance Dance Revolution.[42,43,b] Although one might expect expenditure during video game play to be lower than the actual sport, one must remember that the shoulders and upper limbs serve as the prime movers for both modes of activity. Based on these initial studies of wheelchair sport, it is clear that certain sports can meet the threshold for health (3.0 METs) and functional (1.5 METs) benefits.

List of abbreviations:

CP	**cerebral palsy**
MD	**muscular dystrophy**
MET	**metabolic equivalent task**
RPE	**rating of perceived exertion**
SCI	**spinal cord injury**
SMA	**spinal muscular atrophy**
$\dot{V}O_2$	**oxygen consumption**

Power wheelchair soccer

Power wheelchair soccer is a sanctioned sport for persons with the most severe mobility impairments. Persons who rely on power wheelchairs have limited sport/activity opportunities and are therefore at great risk for a sedentary lifestyle and associated morbidities.[27] The sport of power wheelchair soccer requires all players to use a motorized or electric wheelchair for ambulation, seemly removing the potential for exercise stress. However, players have reported perceived exercise efforts during participation[11,44] (ie, participants reported feeling fatigued and tired after competition, which are typical responses to an exercise stimulus). Although unexpected, this outcome may be supported by acute physiological responses demonstrated during activity. An initial physiological study on power wheelchair soccer reported that 71% of participants were able to sustain 55% of maximum heart rate across an entire match.[45] This acute response would meet a moderate-intensity threshold; however, the study did not control for endocrine contributions to the response. Therefore, it is not clear if the acute heart rate increase was caused by exercise stress or an elevated hormonal response to game play.

If exercise stress is demonstrated during power wheelchair soccer, this sport may be an effective therapeutic modality to reduce morbidity risk (3 METs) or improve functional capacity (1.5 METs) among persons with profound mobility impairments.[9,46-48] This possibility would be a meaningful outcome to therapists, physicians, and participants because few physical activity opportunities exist for power wheelchair users. Individuals dependent on electric wheelchairs face the greatest environmental and social barriers to physical activity, and the need to examine the potential benefits of a viable sport option is warranted. To determine if power wheelchair soccer exceeds either a light- or moderate-intensity threshold, it is necessary to assess exercise intensity during actual participation. Therefore, the purpose of this study was to determine the exercise intensity during power wheelchair soccer activity. Our hypothesis, based on previous studies examining acute responses to power wheelchair soccer, was that participants would sustain light-intensity, if not moderate-intensity, exercise during power wheelchair soccer.

Methods

Participants

Participants (N=30) were recruited from 13 regional teams from the Midwestern, Northeastern, and Southeastern United States. A description of the project was forwarded to players through team coaches, but individuals had the option to participate so that there was no coercion. A convenience sample of approximately 2−3 of each team's athletes chose to participate within 1 month of recruitment and consisted primarily of players who were male (n=21, 70%) and white (n=25, 83%). Being a member of a US Power Soccer Association team was the only eligibility criterion. Typical of power wheelchair soccer athletes, participants had a wide range of ages and experience levels (table 1). Power wheelchair soccer was the only adaptive sport experience among the majority of participants (n=18, 60%); however, the participants' average of 7 years of power wheelchair soccer experience shows the veteran status of the group. The participant sample

Table 1 Participant demographics

Descriptive Variables	Mean ± SD	Range
Sample		
Age (y)	29.40±15.51	7.00−63.00
Height (cm)	162.79±15.20	109.00−187.96
Weight (kg)	63.91±19.55	27.21−105.20
Body mass index	24.11±6.47	12.03−39.56
Years in power soccer	7.91±3.93	0.33−15.00
Years in disability sport	12.44±9.73	0.33−40.00

consisted of persons with amputations (n=1), arthrogryposis (n=3), cerebral palsy (CP) (n=6), spinal muscular atrophy (SMA) (n=11), other types of muscular dystrophy (MD) (n=4), spinal cord injury (SCI) (n=4), and traumatic brain injury (n=1). Institutional review board approval was obtained before the study, and all players were required to provide informed consent or assent with corresponding parent consent before participation.

Instrument

Exercise intensity was assessed with 2 instruments. A subjective assessment of exercise intensity was measured with Borg's 6 to 20 rating of perceived exertion (RPE) scale. The RPE scale has been used as a valid assessment of effort in the sample populations, specifically in persons with CP,[49] MD,[49,50] and SCI.[51] The scale criterion associated with light-intensity exercise in the general population is a score of 11 (fairly light), and the criteria associated with moderate-intensity exercise is a score of 12−13 (somewhat hard).

An objective assessment of exercise intensity was measured using 1 of 2 telemetric portable gas analyzers (K4 b2[c] and Oxycon Mobile[d]). The analyzers were powered 30 minutes before testing and calibrated according to the instruction manual with gases of known concentration (16% O_2 and 4% CO_2) before each test day. Each system was secured to the upper chest with a harness in a position to minimize impact on movement of the participant. A flow sensor unit was connected to a face mask fitted over the participants' mouth and nose (Hans Rudolph flow sensor[e]). These units detect airflow by the rotation of a low-resistance turbine. Studies have shown both K4 b2 and Oxycon Mobile to be valid and reliable systems for the measurement of respiration parameters.[52,53] These systems measure the volume of oxygen consumption ($\dot{V}O_2$) during activity, which is an objective measure of exercise intensity. $\dot{V}O_2$ can be reported in multiple units, and we chose to report units in METs so that we could compare sustained power wheelchair soccer intensity against the 1.5- and 3.0-MET thresholds of light-intensity and moderate-intensity exercise, respectively. $\dot{V}O_2$ was measured breath by breath with both systems.

Procedures

Data were collected during regularly scheduled power wheelchair soccer practices or games. Power wheelchair soccer is played in two 20-minute continuous-play halves; therefore, we delimited assessment to continuous game play conditions rather than drill activity that included stoppage time for coach instruction. At the start of a practice or game, researchers fitted 1−2 participants with a portable metabolic analyzer and recorded $\dot{V}O_2$ every 30 seconds. $\dot{V}O_2$ data were converted to METs using a denominator of 3.5, with the exception of persons with SCI, in which case 2.7 was used to adjust for reduced fat-free muscle mass because of atrophy in this population.[40] All recordings were made while the participant was in his or her game chair, and the portable equipment was a successful instrument option because players were able to participate without interruption of data collection or actual game play. METs were measured over 5 minutes of rest and at least 10 minutes of continuous game play activity with the average of 30-second scores reflecting each condition score. These time frames were selected because they have been used previously to collect steady-state exercise intensity data, specifically $\dot{V}O_2$, for the sample population.[42,54] Also, the first 30 seconds of game play was excluded from analyses so that participants had time to acclimate to the new stage.[42] RPE was assessed at the conclusion of at least 10 minutes of continuous game play.

During practices, game play data were collected on 2 players at a time during interteam scrimmages (1 player from each team). Scrimmages typically lasted 10−15 consecutive minutes without stoppage in play. This time limit was imposed because of the need for teams to work on other activities within the given practice time. We collected scores on a regulation power wheelchair soccer court at 3 distinct practice sites (1 rehabilitation facility, 1 church gym, and 1 school gym). Data were collected within a 2-day period at each facility in March, April, and June 2015. Data from 16 independent participants, using both gas analyzers, were collected during practice conditions. During games, game play data were collected on 1 player at a time during each game half. Halves lasted 20 consecutive minutes without stoppage in play. We aligned testing around conference league play so that we again collected data within a 2-day period (November 2015) on a regulation court at an alternative rehabilitation facility. Data from 14 independent participants, using only the K4 b2 unit, were collected during power wheelchair soccer games.

Although data collection delimited to 1 setting or the other would have enhanced the internal validity of the study, the dual collection settings enabled us to double our anticipated sample size, maximizing the external validity of the current findings. This point is important because, despite the growth in power wheelchair soccer, it is difficult to recruit multiple players in any given region, requiring data collection at multiteam sites. A sample size of 10 participants was needed to detect a mean increase from 1.0−1.5 METs with 80% power (http://biomath.info/power/prt.htm). Although 16 participants were initially recruited, we did not have at least 10 persons with the same type of physical disability. Fortunately, the ability to collect data on regulation courts under similar continuous game play conditions at each facility within 2-day sessions eliminated potential bias caused by possible seasonal variation or training effects on responses.

Analysis

Data check

Because we collected data in 2 settings with 2 gas analyzers, our first priority was to ensure that data should be grouped together for analyses. We conducted independent group *t* tests on mean rest, game play, and RPE scores to ensure no significant differences existed between metabolic units or between practice and game participants ($P<.05$).

Exercise intensity

Mean METs and RPE were computed for game play to determine if power wheelchair soccer participants sustained light- or moderate-intensity exercise during game play. A repeated measures *t* test was conducted on METs to determine if exercise intensity increased significantly from 5 minutes of rest ($P<.05$). SPSS 22.0[f] for Mac was used to analyze all descriptive and inferential statistics. Additionally, we visually inspected scores of players to examine the potential of disability type to influence acute responses.

Results

Each participant had a complete data set with the exception of 1 practice player missing the 5-minute rest period (because of time limitation). No significant mean differences existed between gas analyzers or practice/game participants on mean rest, game play, or RPE ($P>.05$) (table 2); therefore, all data were analyzed collectively as 1 sample (N = 30). Regarding exercise intensity, participants demonstrated light-intensity exercise, but not moderate-intensity exercise, during game play conditions while using a motorized wheelchair (see table 2). Energy expenditure increased by 34% from the rest period to game play, and this increase was significant ($P<.01$). This increase in energy expenditure was supported by a mean RPE score of 12.8 after game play conditions. This perceptual effort score is evaluated as somewhat hard on the Borg scale.

Twenty of the 30 participants sustained light-intensity exercise across 10 minutes of power wheelchair soccer activity (ie, 1.5 METs). Although insufficient statistical power prevented analyses of subgroups, visual inspection of data did not support disability type as a discriminating variable between persons who did and did not sustain light-intensity exercise. The majority of participants with each type of mobility impairment sustained light-intensity exercise; however, there was at least 1 player with each disability who did not.

Discussion

In general, athletes with mobility impairments are capable of sustaining vigorous-intensity exercise (>6 METs) during manual wheelchair sport.[55] However, the current population has the greatest physical challenge to voluntary exercise and, by participating in power wheelchair soccer, are unable to pursue manual wheelchair sport options that result in vigorous-intensity exercise. The purpose of this study was to determine the actual exercise intensity during power wheelchair soccer, and participants sustained 1.8 METs or light-intensity exercise across 10 minutes of game play. Although this intensity does not meet the 3.0-MET threshold associated with reduced chronic disease risk, the ability to surpass and sustain 1.5 METs shows exercise stress during power wheelchair soccer associated with functional benefits. The objective response to power wheelchair soccer was confirmed by a perceived increase in effort, with participants ranking game play as somewhat hard. The current findings identify the ability of most, but not all, players to sustain light-intensity exercise while using a power wheelchair.

Table 2 Exercise intensity during power soccer game play (N = 30)

Data Collection Conditions	n	Rest METs	Game play METs	RPE*
Unit 1	8	1.36±0.51	1.82±0.72	12.88±3.53
Unit 2	24	1.32±0.39	1.76±0.78	12.63±2.13
Practice	16	1.29±0.38	1.83±0.55	12.33±2.77
Tournament	14	1.41±0.56	1.78±0.76	13.42±3.26
Sample	30	1.35±0.47	1.81±0.65	12.80±3.11

NOTE. Values are mean ± SD.
* Borg RPE scale (6–20).

Comparison to power wheelchair soccer research

The current findings are consistent with initial research into power wheelchair soccer. Barfield et al[45] reported that 71% of athletes with CP and MD sustained moderate-intensity heart rates during power wheelchair soccer matches. Heart rate can be influenced by mechanisms associated with physical disability (eg, cocontraction and increased muscle tone); therefore, the direct assessment of energy expenditure in the current study is likely a more accurate measure of exercise intensity. Regardless, our findings and those reported by Barfield reflect sustained exercise stress during game play. This finding is further supported by an increase in energy expenditure from the rest period to drill conditions and drill to game play followed by a decrease in exercise intensity during cooldown activities during practice sessions (data not reported). Even with only a few empirical studies on power wheelchair soccer, early evidence supports the ability of players to sustain light-intensity exercise.

The aforementioned physiological data reflect the objective exercise stress during power wheelchair soccer reported on 2 distinct samples. Jeffress[44] conducted a longitudinal study of 35 power wheelchair soccer participants and identified exercise fatigue as a major theme from qualitative responses. His sample participants repeatedly stressed that power wheelchair soccer was tiring because of its exercise effect. Perceived exertion was also reported among a smaller sample (N = 25) of power wheelchair soccer athletes.[11] These athletes reported that exercise (ie, power wheelchair soccer) was difficult and a major barrier to regular physical activity. The increase in RPE to somewhat hard in the current study supports the affective perceptions from both these samples.

Comparison to alternative physical activities

The exercise intensity sustained in the current study is consistent with a number of functional tasks listed in the compendium of physical activities including bathing, eating, and washing dishes.[56] In essence, power wheelchair soccer energy expenditure surpassed the 1.5-MET threshold for sedentary activity and is comparable with a number of basic activities of daily living.[20] Although light-intensity activity may not have the same health benefits as sustained moderate-intensity exercise, power wheelchair soccer requires energy expenditure consistent with everyday self-care activities reported for the general population. Based on the principle of use/disuse, this activity may contribute to increased longevity of independence and self-care skills. However, caution is warranted with this assumption because energy expenditure estimates in the compendium have yet to be validated for varied populations with mobility impairments.

In addition to functional activities, the acute response in the current study is similar to the 1.83–2.7 METs reported during circuit training in manual wheelchair users with SCI.[40] It is

difficult to speculate as to how power wheelchair activity may approximate manual wheelchair intensity, but the need to compensate for atypical muscle tone and involuntary muscle activity may contribute, at least among players with CP.[57] The need to maintain balance while in the chair, the need to generate isometric contractions to receive impact, or the need to decelerate the body after an abrupt spin or stop may also account for some of the increased energy expenditure during power wheelchair soccer. The mechanisms that explain the actual intensity increase from the 5-minute rest period need further investigation.

Evaluation by participant group

Although statistical power was lacking to analyze each group, visual inspection of individual data revealed 2 important findings in this study. The primary finding is that the majority of participants sustained light- or moderate-intensity exercise during power wheelchair soccer (n=20, 67%). At least two-thirds of players within each disability group surpassed 1.5 METs during game play, with the exception being the double amputee and athletes with a particular form of MD, namely SMA (only 55% of these players sustained >1.5 METs). This outcome highlights the potential of power wheelchair soccer to serve as an exercise or rehabilitation mode for participants with a variety of mobility impairments. The second important outcome is that disability group did not distinguish responders from nonresponders. In other words, disability group itself did not distinguish those who sustained light-intensity exercise and those who did not. Although the subsamples are too small to draw conclusions, the majority of participants with each type of disability were able to sustain 1.5 METs during game play including individuals with arthrogryposis (2/3), CP (5/6), MD other than SMA (3/4), SCI (3/4), and SMA (6/11). This finding has important applications to rehabilitation and therapeutic exercise prescription because questions remain as to which factors distinguish persons able to sustain light-intensity exercise during power wheelchair soccer (ie, responders) and those who are not (ie, nonresponders).

Measuring exercise intensity

Although there are multiple ways to examine the exercise intensity of a sport (or energy demand for a given sport), we chose to use $\dot{V}O_2$ expressed as METs (1 MET=3.5 $mL \cdot kg^{-1} \cdot min^{-1}$). Assessment of $\dot{V}O_2$ is a better option than heart rate in this sample because persons with mobility impairments can have either blunted or accelerated heart rate responses to aerobic and muscular work, making estimates of actual intensity unreliable. This consideration is especially true for persons with CP[26,58] and SPI.[51,59] However, METs can be used to determine light- and moderate-intensity thresholds as well as to compare against established activities on various compendiums.[40,56] Although 1.5 and 3.0 METs may be a meaningful threshold to scientists and practitioners, a comparison of power wheelchair soccer with similar compendium activities and self-care skills may be more meaningful to participants and caregivers.

Study limitations

The major limitation in the current study is the heterogeneous sample. Caution is warranted when extrapolating these results because physiological responses can vary within and across disability types. To address this limitation, we recruited a large sample size. As a result, the sample findings are robust, less likely affected by 1 particular group or disability. We maximized sample size by collecting data under both interteam scrimmages and conference games. These conditions were synonymous because both offered continuous game play against an opponent with no stoppage time. Regardless, future research must test current findings against larger samples of stratified mobility impairment groups (n=10 per group). A second limitation is that data were collected on-site. This design prevented the researchers from assessing true resting $\dot{V}O_2$; therefore, scores during the 5-minute rest period are likely higher than actual resting intensity. To reduce the impact of this limitation, we determined METs with a denominator of 3.5 (or 2.7 for persons with SCI) rather than actual resting values. Future research should assess true resting energy expenditure so that MET values are relative to actual resting values.

It is worth noting that one should not necessarily use the current MET values to determine calorie needs. Although assessment of $\dot{V}O_2$ is a valid assessment of energy expenditure, individuals with SPI and CP may have an altered basal metabolic rate, rendering the use of METs less useful for energy need usage.[60] Also, the use of RPE may, ultimately, be a more practical mechanism to estimate energy expenditure (exercise intensity) during disability sport.[49,61] Future research should investigate the suitability of RPE to determine energy expenditure in power wheelchair soccer. Finally, our study did not identify mechanisms that distinguished responders from nonresponders. Future studies on identifying mechanisms that allow players to reach light-intensity exercise during power wheelchair soccer are needed.

Conclusions

In conclusion, persons with mobility impairments demonstrated light-intensity exercise during power wheelchair soccer. This objective assessment was supported by the perceived somewhat hard effort reported by participants during game play. Although the threshold may not be sufficient to decrease morbidity risk (ie, <3.0 METs), the sustained energy expenditure was consistent with intensities sufficient to enhance functional capacity and performance of daily living activities (ie, 1.5 METs). The external validity of the current findings seems strong because the sample size (N=30) had adequate power, and the acute responses were similar across players with different disability types and varied game play conditions.

Suppliers

a. Wii boxing and tennis; Nintendo.
b. Dance Dance Revolution; Konami.
c. K4 b2 Portable metabolic cart; Cosmed.
d. Oxycon Mobile metabolic cart; Care Fusion Respiratory Care.
e. Hans Rudolph flow sensor; Hans Rudolph, Inc.
f. SPSS 22.0; IBM.

Keywords

Cerebral palsy; Muscular atrophy, spinal; Muscular dystrophies; Rehabilitation; Spinal cord injuries

Corresponding author

J.P. Barfield, DA, Box 6957, Radford University, Radford, VA 24142. *E-mail address:* abarfield@radford.edu.

References

1. Blair SN, Brodney S. Effects of physical inactivity and obesity on morbidity and mortality: current evidence and research issues. Med Sci Sports Exerc 1999;31(11 Suppl):S646-62.
2. Paffenbarger RS Jr, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. N Engl J Med 1986;314:605-13.
3. Centers for Disease Control and Prevention (CDC)National Center for Health Statistics. DATA 2010. Hyattsville: CDC; 2010. Available at: http://wonder.cdc.gov/data2010/focus.htm. Accessed September 3, 2015.
4. Haisma JA, Bussmann JB, Stam HJ, et al. Physical fitness in people with a spinal cord injury: the association with complications and duration of rehabilitation. Clin Rehabil 2007;21:932-40.
5. Haisma JA, van der Woude LH, Stam HJ, Bergen MP, Sluis TA, Bussmann JB. Physical capacity in wheelchair-dependent persons with a spinal cord injury: a critical review of the literature. Spinal Cord 2006;44:642-52.
6. Malone LA, Barfield JP, Brasher JD. Perceived benefits and barriers to exercise among persons with physical disabilities or chronic health conditions within action or maintenance stages of exercise. Disabil Health J 2012;5:254-60.
7. Kuperminc MN, Stevenson RD. Growth and nutrition disorders in children with cerebral palsy. Dev Disabil Res Rev 2008;14:137-46.
8. Giacobbi PR Jr, Stancil M, Hardin B, Bryant L. Phyiscal activity and qualtiy of life experienced by highly active individuals with physical disabilities. Adapt Phys Activ Q 2008;25:189-207.
9. Devillard X, Rimaud D, Roche F, Calmels P. Effects of training programs for spinal cord injury. Ann Readapt Med Phys 2007;50. 490-8, 480-9.
10. Nooijen CF, de Groot S, Postma K, et al. A more active lifestyle in persons with a recent spinal cord injury benefits physical fitness and health. Spinal Cord 2012;50:320-3.
11. Barfield JP, Malone LA. Perceived exercise benefits and barriers among power wheelchair soccer players. J Rehabil Res Dev 2013;50:231-8.
12. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 2011;43:1334-59.
13. United States Department of Health and Human Services. 2008 physical activity guidelines for Americans. Washington, DC: United States Department of Health and Human Services; 2008.
14. Manns PJ, Dunstan DW, Owen N, Healy GN. Addressing the nonexercise part of the activity continuum: a more realistic and achievable approach to activity programming for adults with mobility disability? Phys Ther 2012;92:614-25.
15. Warms CA, Whitney JD, Belza B. Measurement and description of physical activity in adult manual wheelchair users. Disabil Health J 2008;1:236-44.
16. Prizer LP, Gay JL, Gerst-Emerson K, Froehlich-Grobe K. The role of age in moderating the association between disability and light-intensity physical activity. Am J Health Promot 2016;30:e101-9.
17. Furmaniuk L, Cywinska-Wasilewska G, Kaczmarek D. Influence of long-term wheelchair rugby training on the functional abilities in persons with tetraplegia over a two-year post-spinal cord injury. J Rehabil Med 2010;42:688-90.
18. Sporner ML, Fitzgerald SG, Dicianno BE, et al. Psychosocial impact of participation in the National Veterans Wheelchair Games and Winter Sports Clinic. Disabil Rehabil 2009;31:410-8.
19. van Koppenhagen CF, Post M, de Groot S, et al. Longitudinal relationship between wheelchair exercise capacity and life satisfaction in patients with spinal cord injury: a cohort study in the Netherlands. J Spinal Cord Med 2014;37:328-37.
20. Peterson MD, Lukasik L, Muth T, et al. Recumbent cross-training is a feasible and safe mode of physical activity for significantly motor-impaired adults with cerebral palsy. Arch Phys Med Rehabil 2013; 94:401-7.
21. Mansoubi M, Pearson N, Clemes SA, et al. Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. BMC Public Health 2015;15:516.
22. Blair CK, Morey MC, Desmond RA, et al. Light-intensity activity attenuates functional decline in older cancer survivors. Med Sci Sports Exerc 2014;46:1375-83.
23. McVeigh SA, Hitzig SL, Craven BC. Influence of sport participation on community integration and quality of life: a comparison between sport participants and non-sport participants with spinal cord injury. J Spinal Cord Med 2009;32:115-24.
24. van Langeveld SA, Post MW, van Asbeck FW, et al. Comparing content of therapy for people with a spinal cord injury in postacute inpatient rehabilitation in Australia, Norway, and The Netherlands. Phys Ther 2011;91:210-24.
25. Zamuner AR, Silva E, Teodori RM, Catai AM, Moreno MA. Autonomic modulation of heart rate in paraplegic wheelchair basketball players: linear and nonlinear analysis. J Sports Sci 2013;31:396-404.
26. Kelly M, Legg D. On-land community-based aerobic and strength training program for children with cerebral palsy. Eur J Adapt Phys Act 2009;2:7-20.
27. Kumar A, Karmarkar AM, Collins DM, et al. Pilot study for quantifying driving characteristics during power wheelchair soccer. J Rehabil Res Dev 2012;49:75-82.
28. Groff DG, Lundberg NR, Zabriskie RB. Influence of adapted sport on quality of life: perceptions of athletes with cerebral palsy. Disabil Rehabil 2009;31:318-26.
29. Wessel RD, Wentz J, Markie L. Power soccer: experiences of students using power wheelchairs in a collegiate athletic club. J Postsecond Educ Disabil 2011;24:147-59.
30. Goosey-Tolfrey V, Castle P, Webborn N, Abel T. Aerobic capacity and peak power output of elite quadriplegic games players. Br J Sports Med 2006;40:684-7.
31. Wu SK, Williams T. Factors influencing sport participation among athletes with spinal cord injury. Med Sci Sports Exerc 2001;33:177-82.
32. Anneken V, Hanssen-Doose A, Hirschfeld S, Scheuer T, Thietje R. Influence of physical exercise on quality of life in individuals with spinal cord injury. Spinal Cord 2010;48:393-9.
33. Martin JJ. Multidimensional self-efficacy and affect in wheelchair basketball players. Adapt Phys Activ Q 2008;25:275-88.
34. Shapiro DR, Martin JJ. The relationships among sport self-perceptions and social well-being in athletes with physical disabilities. Disabil Health J 2014;7:42-8.
35. Perrier MJ, Shirazipour CH, Latimer-Cheung AE. Sport participation among individuals with acquired physical disabilities: group differences on demographic, disability, and Health Action Process Approach constructs. Disabil Health J 2015;8:216-22.
36. Abel T, Platen P, Rojas Vega S, Schneider S, Struder HK. Energy expenditure in ball games for wheelchair users. Spinal Cord 2008;46: 785-90.
37. Croft L, Dybrus S, Lenton J, Goosey-Tolfrey V. A comparison of the physiological demands of wheelchair basketball and wheelchair tennis. Int J Sports Physiol Perform 2010;5:301-15.
38. Perez J, Rabadan M, Pacheco J, Sampedro J. Heart rate assessment during wheelchair basketball competition: its relationship with functional classification and specific training design. In: Higgs C, Vanlandewijck Y, editors. Perspectives. The multidisciplinary series of physical education and sport science. 7th ed. Berlin: International Council of Sports Science; 2007. p 151-74.
39. Schmid A, Huonker M, Stober P, et al. Physical performance and cardiovascular and metabolic adaptation of elite female wheelchair

basketball players in wheelchair ergometry and in competition. Am J Phys Med Rehabil 1998;77:527-33.
40. Collins EG, Gater D, Kiratli J, Butler J, Hanson K, Langbein WE. Energy cost of physical activities in persons with spinal cord injury. Med Sci Sports Exerc 2010;42:691-700.
41. Roy JL, Menear KS, Schmid MM, Hunter GR, Malone LA. Physiological responses of skilled players during a competitive wheelchair tennis match. J Strength Cond Res 2006;20:665-71.
42. Howcroft J, Klejman S, Fehlings D, et al. Active video game play in children with cerebral palsy: potential for physical activity promotion and rehabilitation therapies. Arch Phys Med Rehabil 2012; 93:1448-56.
43. Hurkmans HL, van den Berg-Emons RJ, Stam HJ. Energy expenditure in adults with cerebral palsy playing Wii Sports. Arch Phys Med Rehabil 2010;91:1577-81.
44. Jeffress MS. Communication, sport and disability: the case of power soccer. Surrey, UK: Ashgate; 2015.
45. Barfield JP, Malone LA, Collins JM, Ruble SB. Disability type influences heart rate response during power wheelchair sport. Med Sci Sports Exerc 2005;37:718-23.
46. Ensrud E, Kissel JT. Aerobic exercise in muscular dystrophy: gain without pain. Neurology 2015;85:392-3.
47. Siciliano G, Simoncini C, Giannotti S, Zampa V, Angelini C, Ricci G. Muscle exercise in limb girdle muscular dystrophies: pitfall and advantages. Acta Myol 2015;34:3-8.
48. Verschuren O, Peterson MD, Balemans AC, Hurvitz EA. Exercise and physical activity recommendations for people with cerebral palsy. Dev Med Child Neurol 2016;58:798-808.
49. Fong DT, Yam KY, Chu VW, Cheung RT, Chan KM. Upper limb muscle fatigue during prolonged Boccia games with underarm throwing technique. Sports Biomech 2012:441-51.
50. Love JA, Benson J. Community use of a pushrim activated power-assisted wheelchair by an individual with facioscapulohumeral muscular dystrophy. Physiother Theory Pract 2006;22: 207-18.
51. Goosey-Tolfrey V, Lenton J, Goddard J, Oldfield V, Tolfrey K, Eston R. Regulating intensity using perceived exertion in spinal cord-injured participants. Med Sci Sports Exerc 2010;42:608-13.
52. Duffield R, Dawson B, Pinnington HC, Wong P. Accuracy and reliability of a Cosmed K4b2 portable gas analysis system. J Sci Med Sport 2004;7:11-22.
53. Rosdahl H, Gullstrand L, Salier-Eriksson J, Johansson P, Schantz P. Evaluation of the Oxycon Mobile metabolic system against the Douglas bag method. Eur J Appl Physiol 2010;109:159-71.
54. McCrory MA, Kim HR, Wright NC, Lovelady CA, Aitkens S, Kilmer DD. Energy expenditure, physical activity, and body composition of ambulatory adults with hereditary neuromuscular disease. Am J Clin Nutr 1998;67:1162-9.
55. Campbell IG, Williams C, Lakomy HK. Physiological and metabolic responses of wheelchair athletes in different racing classes to prolonged exercise. J Sports Sci 2004;22:449-56.
56. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc 2011;43:1575-81.
57. Dirienzo LN, Dirienzo LT, Baceski DA. Heart rate response to therapeutic riding in children with cerebral palsy: an exploratory study. Pediatr Phys Ther 2007;19:160-5.
58. Keefer DJ, Tseh W, Caputo JL, Apperson K, McGreal S, Morgan D. Comparison of direct and indirect measures of walking energy expenditure in children with hemiplegic cerebral palsy. Dev Med Child Neurol 2004;46:320-4.
59. Valent LJ, Dallmeijer AJ, Houdijk H, et al. The individual relationship between heart rate and oxygen uptake in people with a tetraplegia during exercise. Spinal Cord 2007;45:104-11.
60. Magnuson B, Peppard A, Flomenhoft D. Hypocaloric considerations in patients with potentially hypometabolic disease states. Nutr Clin Pract 2011;26:253-60.
61. Leicht CA, Bishop NC, Goosey-Tolfrey VL. Submaximal exercise responses in tetraplegic, paraplegic and non spinal cord injured elite wheelchair athletes. Scand J Med Sci Sports 2012;22:729-36.