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ORIGINAL

RECREATIONAL WATER SKIING IN PEOPLE WITH PARAPLEGIA: A STUDY OF THREE CASES

ESQUÍ NÁUTICO RECREATIVO EN PERSONAS CON PARAPLEJIA: A PROPÓSITO DE TRES CASOS

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ABSTRACT

Objectives: the cardiorespiratory fitness and the intensity of effort were analyzed during the recreational practice of slalom water skiing. Methodology: three moderately active water skiers with paraplegia participated. They performed an incremental test on an arm ergometer to determine their VO2peak and ventilatory thresholds and completed 3 sessions of water skiing, separated by 48h, where the HR was recorded every 5 s. Results: they obtained a VO2peak of 22.3 ± 0.6 mL·kg-1·min-1 and the ventilatory thresholds were analyzed at ~80 and ~50% of the VO2peak. The average heart rate in the water ski sessions was 111 bpm, which represented an intensity of ~45% of the heart rate reserve (HRR), remaining above 40% of the HRR ~12 min. Conclusion: the moderate intensity of recreational slalom skiing could serve to maintain or improve the cardiorespiratory fitness in these three people with paraplegia.

KEY WORDS: Intensity of effort; Heart rate; Water skiing; Spinal cord injury; Rehabilitation.

RESUMEN

Objetivos: se analizaron la condición cardiorrespiratoria y la intensidad de esfuerzo durante la práctica recreativa del esquí náutico de slalom. Metodología: participaron tres esquiadores náuticos con paraplejia moderadamente activos. Realizaron un test incremental en un ergómetro de brazos para determinar su VO_{2pico} y los umbrales ventilatorios y completaron 3 sesiones de práctica de esquí náutico, separadas por 48h, registrándose la FC cada 5 s. Resultados: obtuvieron un VO_{2pico} de 22,3 ± 0,6 $mL \cdot kg^{-1} \cdot min^{-1}$ y los umbrales ventilatorios se analizaron al ~80 y ~50% del VO_{2pico}. La FC media en las sesiones de esquí náutico fue de 111 ppm, lo que representó una intensidad de ~45% de la FC de reserva (FCR), permaneciendo por encima del 40% de la FCR ~12 min. Conclusión: la intensidad moderada de la práctica recreativa de esquí náutico de slalom podría servir para mantener o mejorar la condición cardiorrespiratoria en estas tres personas con paraplejia.

PALABRAS CLAVE: Intensidad de esfuerzo; Frecuencia cardiaca; Esquí náutico; Lesión medular; Rehabilitación.

INTRODUCTION

Spinal cord injury (SCI), a severe cause of disability, presents with permanent motor and/or sensory alterations and other bodily functions below the level of the injury. It often involves using a wheelchair or depending on the upper limb to move and perform activities of daily living (ADLs). Thus, people who experience an SCI are considered as the population group with the greatest physical inactivity and consequently increases the risk of secondary health complications (Martin Ginis, Jörgensen, and Stapleton, 2012). The sedentary lifestyle situates these people in the lowest spectrum of fitness levels (Nash, 2005), which undermines their ability to perform correctly in ADLs. In fact, it is estimated that only 25% of healthy young people with paraplegia have the level of physical condition required to be independent in their lives (Martin Ginis et al., 2012). The cardiorespiratory condition, as a component of physical condition, is relevant for independence, health and quality of life although it is very reduced in this population (Haisma et al., 2006, Hicks et al., 2011), even more with aging and when the injury is greater and more complex (Janssen, Dallmeijer, Veeger, and van der Woude, 2002). A more severe cardiorespiratory condition leads to a decrease in activity and participation, which further reduces the cardiorespiratory condition (Haisma et al., 2006).

The maintenance or improvement of the cardiorespiratory condition in people with SCI is not possible only performing ADLs, whose physical demand does not present the appropriate intensity and duration (Janssen, van Oers, van der Woude and Hollander, 1994). On the contrary, regular participation in exercise and sport programmes allows them to prevent limitations in their mobility and independence (Janssen and others, 1994) and maintain and improve physical capacity (Hicks et al., 2011; Tweedy et al., 2017). There is strong and consistent evidence regarding the effectiveness of exercise programs performed with arm or wheelchair ergometry, three times a week, of moderate to vigorous intensity (40-80% of heart rate reserve, HRR), to increase the aerobic capacity (VO_{2max}) in people with SCI (Hicks et al., 2011). However, leisure-time physical activity in people with SCI is usually carried out at rather moderate intensities, predominantly resistance training, aerobic exercise and wheelchair management (Martin Ginis et al., 2010). To avoid injuries from excessive use of the upper limbs associated with arm pedaling and wheelchair thrust, Durstine, Moore, Painter, and the American College of Sports Medicine (2016) suggest varying this type of activities typically carried out in indoor areas. Thus, Kelly (2016) proposes to improve and/or maintain the physical condition of people with SCI throughout their lives exercising in both hot and cold environments and in indoor and outdoor area. Thus, not only wheelchair sports in sports facilities provide a stimulus to improve the latter (Bernardi et al., 2010, Sindall et al., 2013), but also the sports and recreational activities normally associated with the warmer months and carried out in reservoirs, lakes and seas such as sailing, surfing and water skiing (Kelly, 2016).

Adaptive water skiing has been proposed as a possible *best practice of inclusion* according to criteria of positive impact and sustainability over time, and its practice by people with paraplegia and tetraplegia with varied functional capacities and skill levels is adapted by adopting a sitting position (Suárez-

Iglesias and Suárez-García, 2016). It can be done at a competitive level, especially in the slalom event in the categories MP1-MP5 (International Waterski & Wakeboard Federation, 2016), or more frequently at a recreational level (Lundberg, Bennett, and Smith, 2011). Although the physiological demands of standing water skiing have recently been investigated in relation to their health benefits (Papathanasopoulou et al., 2016), to our knowledge, no work has studied the impact of adaptive water skiing. The analysis of these demands could be of great interest to skiers whose practice is recreational, as well as to competitors and coaches. The objectives of this work conducted on three skiers with paraplegia were to determine their cardiorespiratory fitness and to analyze the intensity of effort made during the practice at a recreational level of slalom water skiing.

MATERIAL AND METHODS

Participants

Primary inclusion criteria for the three skiers with traumatic SCI participating in the study were to have a diagnosis of complete paraplegia (ASIA A) (Kirshblum et al., 2011), absence of contraindications to exercise, achieve 2-3 hours of physical activity per week (moderately active) (Janssen et al., 2002) and accumulate an experience in the recreational practice of slalom skiing for at least one year. All participants were informed about the characteristics of the study and gave their informed consent after knowing the associated risks and benefits. The study was carried out in accordance with the Declaration of Helsinki.

Procedures

Each skier completed a practice session of water skiing from 10 a.m. to 1 p.m. in each of the 3 days analyzed, each separated by 48-hour intervals. Two days before the first practice, in which they had to refrain from any formal sports activity, the body mass of each skier was measured in the laboratory. This was calculated by subtracting the mass of the wheelchair from the total mass of the wheelchair plus the skier with a wheelchair scale SECA 677 (SECA, Hamburg, Germany). In addition, height was determined with the skier lying on a stretcher (Froehlich-Grobe, Nary, Van Sciver, Lee, and Little, 2011). Immediately afterwards, resting HR values (HR_{rest}) were recorded for three minutes by a validated Polar Team System 2 heart rate monitor (Polar Electro Oy, Kempele, Finland) (Engström, Ottosson, Wohlfart, Grundström, and Wisén, 2012). Next, the participant's cardiorespiratory condition was assessed using an arm ergometer while sitting in his wheelchair.

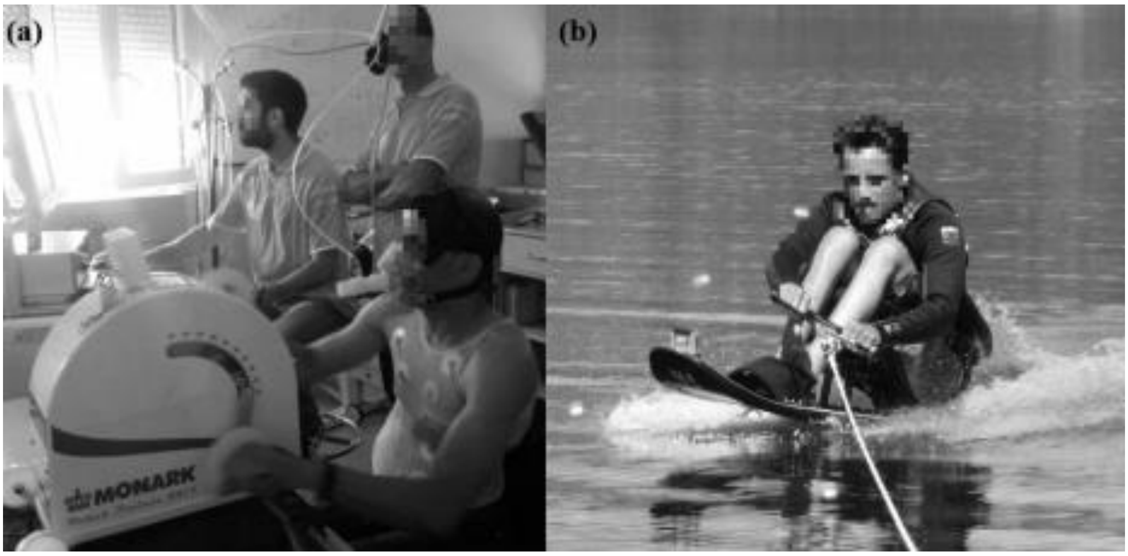

Figure 1. Procedures for (a) maximal cardiorespiratory fitness assessment and (b) recreational practice sessions

Maximal cardiorespiratory fitness assessment

Each test began with a 5 minute warm-up where the skiers pedalled against no resistance at 50 rev·min^{-1} using an arm ergometer with frictional load (Monark Rehab Trainer 881 E, Monark Exercise AB, Varberg, Sweden). The scapula-humeral joint and the axle of the crank were at the same level. Previously, they had emptied their bladders and had become familiar with the ergometer and the pneumotachograph attached to a face mask and connected to a breath-by-breath metabolic unit (Medisoft Ergocard, Medisoft Group, Sorinnes, Belgium) (Figure 1a). Initial workload was set at 25 W with a 5 W increment every minute until exhaustion (De Mello, Silva, Esteves, and Tufik, 2002). Increments were adjusted manually. HR was recorded throughout the test by a 12-lead electrocardiograph (Medisoft Ergocard, Medisoft Group, Sorinnes, Belgium) and every 5 seconds using a heart rate monitor (Polar Team System 2, Polar Electro Oy, Kempele, Finland). The test ended when the participant was unable to maintain the pedaling cadence above 50 rev·min^{-1}. The criterion for a valid maximal test was meeting two of the following conditions: a) a plateau (≤150 mL·min^{-1}) or a maximum peak in the VO_2 after which it decreases with an increase of the load on exhaustion (VO_{2peak}), b) an HR equivalent to ± 10 beats·min^{-1} of the maximum predicted by age (220-age) and, c) a respiratory exchange ratio ≥ 1.10 (Midgley, McNaughton, Polman, and Marchant, 2007). The highest VO_2 value averaging the data every 30 s was considered as VO_{2max}, indicator of aerobic capacity. Similarly, the highest HR value found at the end of the test was considered the HR_{max} of the subjects. Subsequently, according to the criteria of Davis (1985), the aerobic threshold (VT1) and anaerobic threshold (VT2) or aerobic resistance indicator were determined. The ventilatory thresholds were obtained, independently, by two investigators. When there were discrepancies, the opinion of a third researcher was considered.

Adaptive recreational water skiing practice sessions

The skiers were taken to a reservoir and the field heart rates were recorded every 5 s (Polar Team System 2, Polar Electro Oy, Kempele, Finland). There were changing weather conditions, a common situation in water skiing (Bray-Miners et al., 2012). The closest weather station recorded an average air temperature of 24.7 ºC (22.2-30.6ºC) and a wind speed of 17.3 $km \cdot h^{-1}$ (15.0-30.0 $km \cdot h^{-1}$). The skiers were required to perform a standardized 5-min warm-up involving mobility exercises and then they entered the water to perform in each session the various recreational water skiing activities on a typical day (Figure 1b). These tasks were described, typified and grouped into four categories (Table 1) by an expert who made written observational recordings about their duration (Traceable manual digital chronometer VWR, Pennsylvania, USA). In order to adhere to the recommended exercise volume for good cardiometabolic health (Tweedy et al., 2017), ≥10-min activity bouts were performed without rest breaks where the skier returns to the boat. However, taking into account the uncontrollable environmental factors and the preferred activities of the skiers, when someone felt uncomfortable or the symptoms of hypothermia began to appear, they could return to the boat and end the practice session right away. This helped reduce the risks of autonomic dysreflexia in high paraplegia (Nash, 2005). An experienced boat driver and an automatic speed control system were used to set the desired speed for each skier. The smallest speed increment was set at 3 $km \cdot h^{-1}$. All of the ski activities were done with a 18.25-meter-long tow rope and boat speed of 34 km/h^{-1}, although Skier 1 has a speed range up to 40 km/h^{-1}.

Subsequently, HR data were downloaded on a portable PC using specificialized software (Polar Pro Trainer 5, PolarTeam, Polar Electro Oy, Kempele, Finlandia). These data were then analyzed (Nunan et al., 2009). The HRR was calculated as the difference between HR_{max} and HR_{rest} and %HRR was determined by using the Karvonen formula (Karvonen, Kentala, and Mustala, 1957). Intensity of effort was evaluated from HR data in conjunction with the information recorded by the spotter. Variables obtained for each ski category included time spent on practice (min), average HR (HR_{avg}) and practice time in minutes exceeding 40% HRR (the intensity threshold identified for moderate exercise by Tweedy et al., 2017).

Table 1. Category, type and description of activities performed in the three recreational water skiing practices

Category	Type	Description
Deep-water Start		The skier emerges from the water into a proper sitting position and becomes steady and comfortable, until he moves outside one side of the wake
Open water	Outside of the wake and back into	Once the skier is slightly outside of the wake and looking at the boat, he performs a cutting maneuver while moving out farther outside the wake, and then he goes back across the wake
	Rhythm	With the skier positioned wider on the boat (6 m), he goes back and forth across the wake on both sides at a slow pace, with edge control and pressure control, while experiencing counterbalancing and fore-aft balancing.
	Pull hard to the wake	The skier cross the wake side-to-side, avoiding sharp turns. Once crossed, he gradually get farther up alongside the boat equaling the boat speed. This simulates the approaches to the mini-course slalom
Mini-course slalom	Anticipate the turn	The skier travels to the far side of the boat wake to prepare for the entrance gate. He keeps this timing through the mini-course slalom. The aim is to see the buoy when initiating the turn, just before reaching the buoy
	Ski at slower speed	The skier slows down the speed of the boat while running the mini-course slalom. The objective is to complete a rhythmic sequence of turns around the buoys with proper timing, as well as the pull across the wakes. The focus is on technique
Transitions	In the wake	The skier stays up on their sit-ski to ride straight behind the boat. The skier holds the handle
	In water	When the skier falls into the water, either voluntarily or involuntarily, until he is ready to attempt a deep-water start. The skier does not hold the handle

RESULTS

Age, body mass, height and clinical data for our three cases appear in Table 2. Skier 1 had an advanced level (Bray-Miners, Runciman, and Monteith, 2012), Skier 2 had an intermediate-advanced level and Skier 3 had an intermediate level (Runciman, 2011).

Table 2. Personal and injury characteristics

Skier	Age (years)	Body mass (kg)	Height (cm)	Level of thoracic SCI	Years after injury	WS Exp. (years)
1	28	55	177	5	7	3
2	44	65	173	7	25	4
3	35	70	172	12	9	2

Note: *SCI* = spinal cord injury; WS *Exp.* = water skiing experience

Physical fitness: Maximal cardiorespiratory fitness assessment

Maximum, aerobic and anaerobic threshold values in the laboratory test are shown in table 3. Skier 2, who was older and more experienced, obtained the longest test duration and best results in maximal power (PO_{max}), peak oxygen consumption (VO_{2peak}), maximum respiratory exchange ratio (RER_{max}) and maximum ventilation (VE_{max}). Skier 3 attained both lower test duration (23%) and PO_{max} (25%) against the Skier 2, with a similar VO_{2peak} and RER_{max}. Skier 1, reaching a similar HR_{max} and VO_{2peak} to Skier 2, presented a lower test duration (16%) and a lower PO_{max} (19%). Skier 2 had higher aerobic endurance (intensity corresponding to the anaerobic threshold) both in the power and the required VO_2, identified at 87% of the VO_{2peak} and 82% of the HR_{max}. Skier 3 presented intermediate power and VO_2 values, representing anaerobic threshold at 83% of VO_{2peak}, but only at 76% of HR_{max}. On the other hand, Skier 1 shown worse aerobic endurance, having both a worse PO_{max} (33%) and a $\%VO_{2peak}$ (15%) against Skier 2, together with presenting the highest HR corresponding to the 90% of HR_{max} (7% and 14% higher than that of skiers 2 and 3, respectively). This behavior is similar to that shown in the aerobic threshold values, where he presented a similar $\%VO_{2peak}$, a lower PO_{max} (17% and 29% than that of skiers 2 and 3, respectively) and a higher $\%HR_{max}$ (26% and 16%, respectively).

Table 3. Maximum, aerobic and anaerobic threshold values in skiers with paraplegia in the laboratory incremental test on an arm ergometer.

Value	Skier 1	Skier 2	Skier 3	M (SD)
Test time (min)	13.0	15.5	12.0	13.5 (1.8)
PO_{max} (W)	65	80	60	68.3 (10.4)
VO_{2peak} ($L\cdot min^{-1}$)	1.2	1.5	1.6	1.4 (0.2)
VO_{2eak} ($ml\cdot kg^{-1}\cdot min^{-1}$)	22	23	22	22.3 (0.6)
HR_{max} ($beats\cdot min^{-1}$)	182	173	159	171 (12)
RER_{max}	1.4	1.6	1.4	1.5 (0.1)
VE_{max} ($L\cdot min^{-1}$)	61.0	78.5	68.7	69.4 (8.8)
PO-VT2 (W)	40	60	50	50.0 (10.0)
VO_2-VT2 ($L\cdot min^{-1}$)	0.9	1.3	1.3	1.2 (0.2)
VO_2-VT2 ($ml\cdot kg^{-1}\cdot min^{-1}$)	16	20	19	18.3 (2.1)
$\%VO_{2peak}$-VT2 (%)	72	87	83	80.7 (7.8)
HR-VT2 ($beats\cdot min^{-1}$)	163	142	120	142 (22)
$\%HR_{max}$-VT2 (%)	89.6	82.1	75.5	82.4 (7.1)
RER-VT2	1.1	1.2	1.1	1.1 (0.1)
VE-VT2 ($L\cdot min^{-1}$)	31.0	43.1	40.0	38.0 (6.3)
PO-VT1 (W)	25	30	35	30.0 (5.0)
VO_2-VT1 ($L\cdot min^{-1}$)	0.6	0.7	0.9	0.7 (0.2)
VO_2-VT1 ($ml\cdot kg^{-1}\cdot min^{-1}$)	10	11	13	11.3 (1.5)
$\%VO_{2peak}$-VT1 (%)	47	47	57	50.3 (5.8)
HR-VT1($beats\cdot min^{-1}$)	143	91	99	111 (28)
$\%HR_{max}$-VT1 (%)	78.6	52.6	62.3	64.5 (13.1)
RER-VT1	1.0	0.9	0.9	0.9 (0.1)
VE-VT1 ($L\cdot min^{-1}$)	21.2	19.9	23.1	21.4 (1.6)

Note: *M* = mean; *SD* = standard deviation; PO_{max} = maximal power; *W* = watios; VO_{2peak} = peak oxygen uptake; HR_{max} = maximal heart rate; RER_{max} = maximal respiratory exchange ratio; VE_{max} = maximal ventilation; *VT2* = anaerobic ventilatory threshold; *VT1* = aerobic ventilatory threshold

Intensity during adaptive recreational water skiing practice according to time and heart rate

Practice time of adaptive recreational water skiing

When computing the length of practice for each session, Skier 3 was the one who recorded the greatest practice time, more than half in open water. Skier 1 accumulated an 8% lower practice time, predominantly in transitions category. Skier 2 completed the shortest practice time, mainly in open water. The ski category where skiers spent the greatest amount of time was open water, followed by transitions, deep-water start and mini-course slalom. All three skiers spent the least amount of time in mini-course slalom, or not time at all.

Heart rate responses during adaptive recreational water skiing practice

There were clear differences between the skiers for all ski categories and each practice session (see Table 4). The three skiers mean heart rates for all practice sessions represented 65% of the group's lab mean HR_{max} (mean values of 171 beats·min^{-1}), which was comparable across all ski categories, although slightly more intense for mini-course slalom and open water. Skier 1 achieved a low degree of aerobic endurance at laboratory, but the absolute and relative HR_{mean} produced by this subject while skiing represented higher intensity of effort (the HR-VT1 values were similar to mean HR_{mean} values for practices at the intensity corresponding to the aerobic threshold in the incremental test). Thus, Skier 1 showed values 26% and 16% greater than skiers 2 and 3, respectively. Skier 3, with similar aerobic capacity but with lower PO_{max}, HR_{max} and aerobic endurance, had a HR_{med} and a HR-VT1 at the aerobic threshold 10% higher than Skier 2.

The percentage of heart rate reserve (%HRR) was similar in all ski categories, although somewhat more intense for mini-course slalom and open water. Skier 1 performed at a higher intensity of effort (32% and 22% greater than skiers 2 and 3, respectively) (a similar difference for each ski category). Skier 3 exhibited a 10% lower intensity (%HRR) than Skier 2.

Table 4. Duration and intensity of the water skiing practices categories and the three practice sessions for each skier.

	Deep-water start	Open water	Mini-course slalom	Transitions	Total
Total time, min (%)					
Skier 1	3.3 (6.0)	19.4 (3.6)	5.8 (10.6)	26.1 (47.8)	54.6
Skier 2	11.0 (24.3)	23.0 (51.0)	1.2 (2.7)	9.9 (22.0)	45.1
Skier 3	14.9 (25.3)	34.3 (58.1)	-	9. 8 (16.7)	59.0
Total	29.1 (18.3)	76.7 (48.3)	7.0 (4.4)	45.9 (28.9)	158.7
HR_{med} (beats·min^{-1}) M (SD)					
Skier 1	132 (14)	144 (9)	144 (3)	140 (10)	141 (4)
Skier 2	90 (7)	95 (9)	87 (4)	92 (6)	92 (1)
Skier 3	101 (9)	102 (6)	-	86 (13)	100 (9)
Total mean	108 (22)	114 (27)	116 (40)	106 (30)	111 (26)
%HRR, M (SD)					
Skier 1	55.8 (12.4)	66.7 (8.3)	66.8 (2.9)	63.2 (8.4)	64.0 (3.5)
Skier 2	30.3 (6.1)	34.7 (8.0)	28.0 (3.6)	32.3 (5.2)	32.1 (1.1)
Skier 3	43.8 (5.8)	44.3 (5.6)	-	28.6 (12.9)	42.3 (9.0)
Total mean	43.4 (12.6)	48.6 (16.4)	47.4 (27.4)	41.4 (19.0)	46.1 (16.3)

Note: *M* = mean; *SD* = standard deviation; HR_{med} = Mean heart rate; *%HRR* = heart rate reserve in percentage.

Figure 2 reveals that given the complete set of practice sessions, individual differences were observed across participants with regard to the time spent at an intensity greater than 40% of the HRR: mean values of 18.3 min for Skier 1; 3 min for Skier 2; and 15 min for Skier 3. Differences across and within subjects were also found in the percentage of time spent above 40% of HRR. Skier 1 was above 40% of HRR for the entirety of his recorded sessions (lower limit of a moderate level of exercise intensity); Skier 2 only performed at 19%, 12% and 24% of the total time for the 1st, 2nd and 3rd sessions, respectively; and Skier 3 attained 87%, 37% and 100% in the 1st, 2nd and 3rd sessions, respectively.

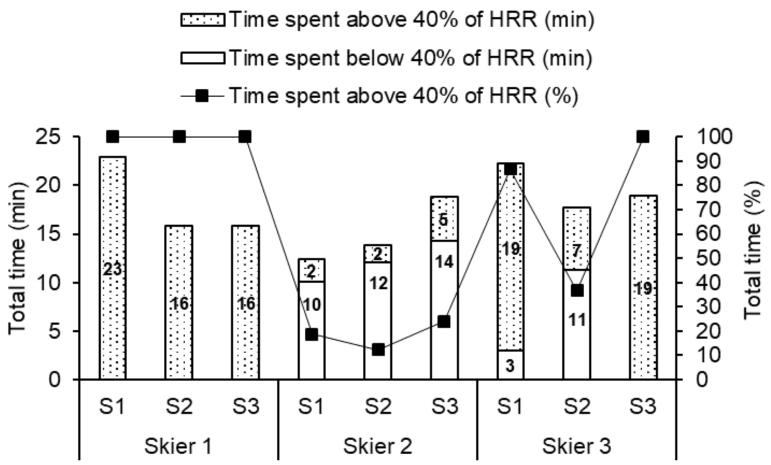

Figure 2. Total time (min) and percentage of the total time recorded above 40% of HRR. *S1* = 1st session; *S2* = 2nd session; *S3* = 3rd session

DISCUSSION

To the best of our knowledge, this study of three cases is the first one to focus on adaptive water skiing. Despite the low number of participants, adaptive water skiing is a sport discipline with moderate levels of global participation (International Waterski & Waterboard Federation, 2016). The objectives were to determine the cardiorespiratory fitness in seated skiers with SCI and to analyze the intensity of effort made during the practice at a recreational level of slalom water skiing. Results show that this activity provides an intensity greater than 40% of HRR, necessary to induce an adequate stimulus to maintain or improve cardiorespiratory fitness (Tweedy et al, 2017). Thus, adaptive water skiing may contribute to improve physical fitness and performance of ADLs in this three subjects with paraplegia.

Physical fitness: Maximal cardiorespiratory fitness assessment

Although there have been several previous studies into adaptive water skiing, the absolute and relative mean VO_{2peak} values produced of 1.4 (SD: 0.2) $L \cdot min^{-1}$ and 22.3 (0.6) $ml \cdot kg^{-1} \cdot min^{-1}$ respectively, were identical to the value reported by Goosey-Tolfrey & Tolfrey (2004) for a female seated water skier (1,4 $L \cdot min^{-1}$). They are also similar to those obtained during a similar protocol on an arm-crank ergometer in subjects with SCI and similar levels of physical activity, with values ranging from 1.0 to 2.3 $L \cdot min^{-1}$ (group's mean of 1,5 $L \cdot min^{-1}$) (Haisma et al., 2006). In addition, our results do not differ from the mean values for incremental arm-crank ergometry (23.1 (7.2) $ml \cdot kg^{-1} \cdot min^{-1}$) reported by Rotstein et al. (1994) for eight players on the Israeli national wheelchair basketball team, where half these players had SCI (complete SCI: T4, T7 and T10; incomplete SCI: L5) and were described as recreationally active.

Skiers participating in this study ranged between the lower limit of *average* aerobic capacity (VO_{2peak} of 22.7 $ml \cdot kg^{-1} \cdot min^{-1}$ and PO_{max} of 70.5 W) and the levels associated to *fair* aerobic capacity (VO_{2peak} of 16.5-22.7 $ml \cdot kg^{-1} \cdot min^{-1}$ and PO_{max} of 52.9-70.4 W), based on physical capacity norms for men with paraplegia (Janssen et al., 2002), with ranges from *poor* (< 16.5 $ml \cdot kg^{-1} \cdot min^{-1}$ and 52.7 W) to *excellent* (> 34.4 $ml \cdot kg^{-1} \cdot min^{-1}$ and 97.8 W). Moreover, our results were half the value of the VO_{2max} of 54.5 (6.2) $ml \cdot kg^{-1} \cdot min^{-1}$ described for male professional able-bodied water skiers (Leggett, Kenney, & Eberhardt, 1996). This could be indicative of a low physical capacity in subjects with paraplegia, having a lower muscle mass and altered autonomic control that impacts responses to exercise, in contrast to fully able-bodied water skiers who exhibit trunk and lower limb muscle activation during water skiing practice in order to accomplish the dynamic balancing (Goosey-Tolfrey y Leicht, 2013; Leggett et al., 1996). Furthermore, during arm-crank ergometry, there is activation of a lower muscle mass leading to lower VO_{2max} and higher local fatigue (Goosey-Tolfrey & Leicht, 2013). This also accords with previous observations (Goll, Wiedemann, y Spitzenpfeil, 2015) among paraplegic and able-bodied alpine skiers.

The VT2 of the subjects is comparable with that of Israeli wheelchair basketball players reported by Rotstein et al. (1994) (142 vs 139 beats·min^{-1}), corroborating the similar aerobic fitness values. Even though the VT2 is the best indicator of aerobic fitness, while the VT1 is considered an indicator of aerobic training intensity or the point when lactate begins to accumulate in the blood, or low-to-moderate intensity zone (Davis, 1985). Our results indicated that the VT1 represents a level of intensity from 47% to 57% of VO_{2peak}, slightly higher than that (40% HRR) established by Tweedy et al. (2017), which is the equivalent to 40% VO_{2max} for healthy adults (American College of Sports Medicine, 2013). It can therefore be assumed that adaptive water skiing intensity during practice conditions in this three subjects achieve the appropriate level to improve aerobic endurance. Nevertheless, there are few studies that have used the VT1 of a ergoespirometry in individuals with paraplegia who participate in any competitive or recreational sports. In this regard, the mean VT1 in terms of VO_2 of 1.1 (0.2) L·min^{-1} observed in sitting-class athletes by Goll et al. (2015) is higher than our value of 0.7 (0.2) L·min^{-1}, but those were athletes of the German Paralympic Alpine Ski Team.

Practice time of adaptive recreational water skiing

This study reveals the prevalence of open water category during the recreational practice of water skiing in three subjects with paraplegia. It is important to note that the training focus for a slalom skier is on accumulating quality ski time to obtain skills for skiing consistently. During open water slalom skiing, the skier is able to focus and think on techniques in a flexible practice environment. Hence, it has been proposed by various authors (Benzel, 1993; Mullins, 2007) as a modality of fitness conditioning that promotes continuity of a practice routine.

Moreover, the subjects recorded 47% of the total time skiing for deep-water starts and transitions categories, with the %HRR showing that these activities do not allow the skier to recover. Deep-water starts are also typical among intermediate level recreational slalom able-bodied skiers (Runciman, 2011). This also accords with recreational abled-bodied participants in other aquatic sports where the environment is somewhat unpredictable, like surfing (Meir, Lowdon, & Davie, 1991). The mean total time spent stationary and paddling represented 35% and 55% of the total time surfing respectively, and the relative intensity of effort required for these activities does not allow to rest (mean heart rates represented 80% and 71% of the laboratory HR_{peak}, respectively).

These outcomes are contrary to the demands of intermittent wheelchair sports, where recovery periods account for 48% of the total game time in basketball (Bloxham, Bell, Bhambhani, & Steadward, 2001) and 80-85% for tennis (Croft, Dybrus, Lenton, & Goosey-Tolfrey, 2010). Hence, the work-to-rest ratio in basketball (1:1) or in tennis (0:2:1) differs from the findings presented here, due to the almost non-existent rest periods during sessions. The goals for the practice were recreation, leisure and maintenance of individual skier's fitness, instead of performance, as a result, the least amount of time was spent on a mini-course slalom activity during every practice session. It is interesting to note that water skiing through a slalom course is very demanding in terms of strength, power, endurance, timing, coordination, and dynamic balance (Mullins, 2007). These complex requirements can have adverse psychological effects even for international skiers with paraplegia (de Bressy de Guast, Golby, Van Wersch, & D'Arripe-Longueville, 2013). Thereby, for Skier 3 no time was recorded for this category due to inherent limitations to his level of skill.

Heart rate responses during adaptive recreational water skiing practice

This is the first study to undertake a necessary quantification of these types of activities in order to examine the physiological demands of water skiing (Bray-Miners et al., 2012). The present findings indicate that during the recreational practice of adaptive water skiing, the mean HR values achieved by the skiers were 55%, 38%, 37% and 24% lower than those in male Paralympic athletes participating in Nordic sit skiing, wheelchair fencing, wheelchair basketball and wheelchair tennis, respectively (Bernardi et al., 2010). This also accords with wheelchair basketball and wheelchair tennis athletes who exhibited higher HR_{mean} values (39% and 32%, respectively) (Croft et al., 2010). Higher values of 16% and 21% were also reported by Bloxham et al. (2001) and Sindall et al. (2013) for wheelchair basketball and wheelchair tennis, respectively.

In the current study, water skiing through a mini-course was found to cause higher values in HR_{mean}, albeit supposing a lower intensity than previously reported for the aforementioned adaptive sports. These results may be explained by the fact that athletes in elite disability sport competition were involved, while our results are gathered from subjects practicing in recreational water skiing. In this regard, Coutts (1988) suggests that practice conditions appeared to elicit lower heart rates than competitions in both team or individual wheelchair sports. A possible explanation for this might be that the athlete is usually stationary or working on individual skills at a slower pace than normal during practice activities. Another possible explanation for this is that our subjects were moderately active and exhibited a fair-to-average aerobic capacity (mean VO_{2max} of 22.3 $ml \cdot kg^{-1} \cdot min^{-1}$), whereas subjects in the aforementioned studies shown greater values of 30.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (Bernardi et al., 2010), 35.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (Croft et al., 2010) or 37.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Bloxham et al., 2001).

These differences may partly be explained by characteristics of selected practice. The greater intensity of wheelchair basketball or tennis reflects the high-intensity, repetitive movements when propelling, turning and slowing down (Coutts, 1988; Goosey-Tolfrey y Leicht, 2013). By contrast, Water skiing is a physically demanding sport involving sustained isometric contractions (Leggett et al., 1996), where muscle mass of the trunk plays a role for stable sitting position when skiing (Goll, Spitzenpfeil, Beer, Thimm, y Bartels, 2015). Heart rate response appeared to be lower during this type of contractions (Lewis et al., 1985), as a result of a rise in blood pressure. On this point, water skiing has principally high static (>50% of maximal voluntary contraction) and low dynamic demands (<40% VO_{2max}) (Mitchell, Haskell, Snell, y Van Camp, 2005).

One of the issues that emerges from these findings is the variable HR responses among skiers. There is evidence that athletes with lesions at or above T6 may have decreased peak heart rates due to altered cardiovascular control and limited amount of functional muscle mass, while HR responses are normal in those with a SCI below that level (Goosey-Tolfrey & Leicht, 2013). However, the recorded water skiing HR do not meet these standards. Skier 1, with SCI level T5, does not demonstrate a decreased HR during exercise. He recorded for each practice session the greatest HR, exceeding always 40% of the HRR. A possible explanation for this might be that he had an advanced level. When performing water skiing activities, higher speeds up to 6 $km \cdot h^{-1}$ compared to other skiers require higher average tow rope loads for every technical gesture and come at the cost of greater physical demands (Bray-Miners et al., 2012).

On the other hand, Skier 2 showed better cardiorespiratory fitness, but spent most of the practice time water skiing at a slower speed that elicited an intensity of effort of ≤40% of HRR. A high inter-individual variability was found in physical strain (%HRR) by Janssen et al. (1994). Physical strain was inversely related to parameters of physical capacity. Likewise, in the three sessions and regardless the activity category, Skier 2 exhibits mean intensities between 28 and 35% of HRR, while presenting the best aerobic capacity. Furthermore, both the older age of the skier and the most prevalent type of muscle contraction may explain a decrease in water skiing intensity. It is now well established that HR response during isometric handgrip fatiguing contractions declines 50% in those with paraplegia between ages 20 and 60 (Petrofsky & Laymon, 2002). Water skiing demands high handgrip forces (Rosa, Di Donato, Balato, D’Addona, & Schonauer, 2016) and can be classified as high static and low dynamic demand (Mitchell et al., 2005). Another possible explanation for this is that this skier was afflicted with scoliosis, causing functional asymmetry. As a result, he performed every technical action more effectively when going over the wake to one side, which probably reduces the workload by exerting less force when moving to the weak side (Goosey-Tolfrey, & Leicht, 2013).

Finally, the individual HR responses were variable among participants in this study. The unpredictable environmental conditions (water temperature and flow, wind speed) or psychological factors (mood, recreational boat traffic, other skiers’ presence) as described for surf (Meir et al., 1991) may have had an impact in their performance. Nevertheless, activities were performed in those areas of the reservoir where the impact of wind and fatigue could be reduced.

Exercise duration and intensity needed to maintain health

There are parallels between heart rate monitoring during adaptive recreational water skiing practice sessions and many of the situations described in the ADLs during rehabilitation. Janssen, van Oers, Veeger, et al. (1994) observed 24 men with SCI (C4-L5) who performed a set of standardised tasks. Entering a car was the most demanding task in terms of physical strain (45,9% of HRR), which is similar to that in our study (46,1%). On the other hand, Koopman, Eken, van Bezeij, Valent, & Houdijk (2013) found that in 31 patients undergoing clinical rehabilitation (including 8 SCI patients with paraplegia), an intensity of 40%

HRR was reached during five types of therapies, and more than half of the time was spent > 40%HRR. Nonetheless, it is difficult to compare the percentage of time spent in moderate-intensity exercise with other sports. Existing reference values are derived from data produced by wheelchair court sports, demanding dynamic efforts and isotonic contractions, many different work-to-rest ratios, and setting the intensity thresholds at higher values.

Aerobic exercise recommendations for people with SCI include a volume that can be accumulated in bouts of ≥10 min (Tweedy et al., 2017). Although the present study's practice sessions were scheduled for different days to fit availability of facilities, water skiing as a recreational activity comprise several daily ski passes that normally last around 15 minutes. It is interesting to note that open water skiing tends to offer flexibility on individual ski time, since the skier does not have to share access to a slalom course (Mullins, 2007). Consequently, daily exercise recommendations for people with SCI (≥30 min of aerobic exercise at >40% HRR) by Tweedy et al. (2017) can be reached in two or three recreational water skiing practice sessions, as seen for skiers 1 and 3. When incorporating water skiing into a healthy lifestyle, it should be noted that those with poorer physical fitness are more likely to benefit from exercising at lower moderate-intensities (Tweedy et al., 2017).

These findings may be somewhat limited by the unpredictable nature of water skiing, the different levels of spine injuries and skill levels of water skiers, causing heterogeneity in activities and practice conditions for the various sessions. Moreover, a more controlled environment would be necessary to minimize the factors that can influence research outcomes. In future investigations, it might be possible to increase our sample size, although a common limitation in adapted physical activity research is the small sample sizes. In this sense, further studies focusing more on the muscular strength requirements and biomechanics for adaptive water skiing are therefore suggested. It can help to understand the sport profile of water skiing for sitting athletes, which should be taken into account when planning proper training sessions.

CONCLUSIONS

In this study of three cases, skiers with paraplegia due to an injury to the spinal cord showed a fair-to-average aerobic capacity when administered a cardiorespiratory fitness test. The recreational practice of adaptive water skiing in the discipline of slalom required the three participants an exercise intensity at a moderate level, based on a percentage of HRR, during water skiing sessions averaging >10 minutes. More than 50% of the recreational water skiing practice sessions of this sample meet the recommended quantity and quality of exercise for developing cardiorespiratory fitness in people with chronic spinal cord injury. However, these conclusions would only be applicable to three cases with clinical heterogeneity.

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