Validation of a maximal incremental skating test performed on a slide board: comparison with treadmill skating

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Original Investigation

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Abstract

Purpose: the aim of this study was to investigate the criterion validity of a maximal incremental skating test performed on a slide board (SB). Methods: Twelve sub-elite speed skaters performed a maximal skating test on a treadmill and on a SB. Gas exchange threshold (GET), respiratory compensation point (RCP) and maximal variables were determined. Results: oxygen uptake ($\dot{V}O_2$) (31.0 ± 3.2 and 31.4 ± 4.1 $mL\cdot min^{-1}\cdot kg^{-1}$), percentage of maximal oxygen uptake ($\dot{V}O_{2max}$) (66.3 ± 4 and 67.7 ± 7.1%), HR (153 ± 14 and 150 ± 12 bpm), and ventilation (59.8 ± 11.8 and 57.0 ± 10.7 $L\cdot min^{-1}$) at GET, and $\dot{V}O_2$ (42.5 ± 4.4 and 42.9 ± 4.8 $mL\cdot min^{-1}\cdot kg^{-1}$), percentage of $\dot{V}O_{2max}$ (91.1 ± 3.3 and 92.4 ± 2.1%), heart rate (HR) (178 ± 9 and 178 ± 6 bpm), and ventilation (96.5 ± 19.2 and 92.1 ± 12.7 $L\cdot min^{-1}$) at RCP were not different between skating on a treadmill and on a SB. $\dot{V}O_{2max}$ (46.7 ± 4.4 vs 46.4 ± 6.1 $mL\cdot min^{-1}\cdot kg^{-1}$) and maximal HR (195 ± 6 vs 196 ± 10 bpm) were not significantly different and correlated ($r = 0.80$ and $r = 0.87$, respectively; $p < 0.05$) between the treadmill and SB. $\dot{V}O_2$ at GET, RCP and $\dot{V}O_{2max}$ obtained on a SB were correlated ($r > 0.8$) with athletes' best time on 1500 m. Conclusions: the incremental skating test on a SB was capable to distinguish maximal ($\dot{V}O_2$ and HR) and submaximal ($\dot{V}O_2$, % $\dot{V}O_{2max}$, HR and ventilation) parameters known to determine endurance performance. Therefore, the SB test can be considered as a specific and practical alternative to evaluate speed skaters.

Keywords: speed skating; incremental test; test validity; intensity thresholds; maximal oxygen uptake

Introduction

A maximal incremental exercise test is a well-established method for determining key parameters of aerobic capacity in humans, such as gas exchange threshold (GET), respiratory compensation point (RCP), and maximal oxygen uptake ($\dot{V}O_{2max}$). Since indices of aerobic capacity such as $\dot{V}O_{2max}$ and physiological exercise intensity thresholds are associated with performance during speed skating competitions[1], a skating-specific incremental test is needed to properly measure these parameters.

Speed skating is characterized by a unique crouched position and side-ways movement of the body that determine the physiological demands. The low posture adopted during speed skating and the long isometric phase of each stroke, followed by concentric phase, results in restriction of blood flow to the lower limbs and high intramuscular forces[2,3]. These specific characteristics are associated with a lower $\dot{V}O_{2max}$ and higher maximal heart rate (HR_{max}) during skating when compared with running or cycling[4,5,6]. Despite the lack of specificity, cycle ergometer or treadmill running tests are widely used in speed skating[7] for monitoring physiological changes and establishing training intensities.

Optimal training adaptations can be obtained from training loads specifically related to the activity itself, due to the specific physiological and neuromuscular demands[8]. As a result, performance evaluations for exercise prescription must be movement specific, valid and reliable [9]. Nobes et al.[10] found no difference in $\dot{V}O_{2max}$ achieved during a maximal skating protocol on treadmill and on ice, suggesting that skating treadmill could be of great value to evaluate speed skaters. However, skating treadmills are very expensive and the athletes need to be highly-skilled and familiar with skating on a treadmill to be able to perform maximally. All these limitations challenge the use of skating treadmills for optimizing training programs through periodic laboratory evaluation.

Skating protocols performed on ice track are even more complicated to perform, as testing conditions are more difficult to control. The necessity of having long periods of test interruptions to collect blood samples may increase data variability which would affect the reliability of the results, limiting the application of incremental cardiorespiratory tests on track[4,5] Moreover, at maximal intensity, it may become biomechanically or technically difficult to skate fast enough to fully challenge the cardiovascular system[11].

As an alternative, some researchers investigated physiological responses obtained during low walking on an oversized motor-driven treadmill, which simulated the posture used in speed skating[12]. Another study investigated physiological responses during a maximal skating test on a slide board[13]. However, the aforementioned studies did not determine the validity of those protocols compared with a real skating activity. Given the importance of assessing different parameters of aerobic function to monitor speed skaters, and considering the technical and cost-related limitations of other testing modalities, the use of a slide board based incremental test to determine endurance performance in a more accessible, valid and laboratory controlled way is warranted.

Therefore, the purpose of this study was to assess the validity of submaximal and maximal aerobic indices related to endurance performance during an incremental test performed on slide board, compared to a similar skating protocol on treadmill. The main hypothesis was that skating on the slide board would elicit similar submaximal and maximal cardiorespiratory responses compared to skating on the treadmill.

Methods

Participants

Twelve (4 male and 8 female) long-track speed skaters (distances between 500 and 5000 m) voluntarily participated in this study. The athlete's mean age, body mass, and height were 18.0 ± 0.9 years, 65.0 ± 6.8 kg, and 1.73 ± 8.80 m, respectively. The speed skaters participated in a systematic training program with a volume of 2 hours/day, 5 days per week, for at least 3 years. According to indicators based on current and past training data[14], this group of individuals fit within the "trained" category and performance level 4. The tests were performed during the competitive season. The skaters' best time average for the 1500 m distance was 2.13 ± 0.14 min. The study was conducted in accordance with ethical standards of the local University Human Research Ethics Committee (REB15-2537), and all participants signed an informed consent form with detailed description about the study protocol.

Design

Participants were instructed to refrain from heavy exercise (any physical activity that was beyond their activities of daily living or a recovery-like exercise session) in the 24 h before each test, maintain a similar diet, and to abstain from the ingestion of stimulants (i.e., caffeine, nicotine) or alcohol. Each subject performed two incremental skating tests to fatigue, separated by two to four days. One test was performed on a treadmill and the other on an instrumented slide board. All participants were familiarized with the treadmill skating protocol, using their own inline skates, at least twice, for a minimum of 30 min 2 to 5 days before the data collection. Participants were familiar with the slide board skating movement as they use it for training.

Methodology

A maximal inline skating protocol was performed on an oversized, motor driven treadmill (2.5 × 3.5 m) (Athletic Republic, Salt Lake City, UT). During the test the athletes wore a safety harness that was attached to an overhead pulley as a precaution to prevent from a potential fall. After 3 min of baseline skating at 8 $km \cdot h^{-1}$, the treadmill skating protocol started at 12 $km \cdot h^{-1}$, and increased by 2 $km \cdot h^{-1}$ every minute until volitional exhaustion despite strong verbal encouragement. We opted to not to change the treadmill grade in order to provide a condition as close as possible to real skating and slide board skating exercises. Because our subjects were well-trained skaters familiar with treadmill skating, they did not have any technical difficulties to skate at high velocities. Therefore, maximum effort was attained and the athletes stopped due to exhaustion, not technical limitations.

A slide board equipped with sensors and connected to custom made software was used for a maximal incremental test, as described elsewhere[13]. Briefly, each athlete skated on a slide board of polyethylene surface (2.0 × 0.6 × 0.2 m) wearing a pair of nylon socks over their shoes while skating. Optical sensors were placed at either extremity of the slide board to determine the athletes' instantaneous skating cadence and a software program was developed to help the athlete keep the pace by providing visual and auditory feedback (Figure 1). After 3 min of baseline skating at 15 push-offs per minute (ppm), the protocol started with a cadence of 30 ppm, and increased by 3 ppm every minute until volitional exhaustion occurred despite strong verbal encouragement (Figure 2). The reliability of this protocol has been previously determined (ICC > 0.9 and typical error of measure expressed as a coefficient of variation < 3.5%)[15].

Throughout each exercise trial pulmonary ventilation ($\dot{V}_E$), respiratory exchange ratio (RER), carbon dioxide production ($\dot{V}CO_2$) and oxygen consumption ($\dot{V}O_2$) were measured breath-by-breath using a portable gas analyzer (K4b2 Cosmed®, Rome, Italy), calibrated according to manufacturer's instructions prior to each test. $\dot{V}O_{2max}$ was considered to be the highest averaged value over a 15-second period during the last stage of the test. HR was collected using radiotelemetry (SP0180 Polar Transmitter; Polar Electro Inc., Kempele, Finland). Blood samples from the fingertip were collected at the end of each test, and at minute one, three and five following the conclusion of the test, to assess peak of blood lactate concentration ($[La]_{peak}$). The Lactate Scout (SensLab GmbH, Leipzig, Germany) analyser was used and calibrated according to the manufacturer's recommendations. The gas exchange threshold (GET) and the respiratory compensation point (RCP) were identified by two blinded experts. If the two reviewers agree within discrepancy of no more than 200 $mL \cdot min^{-1}$ then the average will result in an error no larger than 100 $mL \cdot min^{-1}$, which would be within the lowest detectable noise in the $\dot{V}O_2$ data[16]. Only when a discrepancy was larger than 200 $mL \cdot min^{-1}$ and the potential error was unacceptable, a third reviewer was involved to discuss the thresholds. GET was determined by visual inspection as the $\dot{V}O_2$ at which $\dot{V}CO_2$ began to increase out of proportion in relation to $\dot{V}O_2$, with a systematic rise in $\dot{V}_E$-to-$\dot{V}O_2$ relation and end-tidal partial pressure of O_2 (PO_2) whereas the ventilatory equivalent of $\dot{V}CO_2$ ($\dot{V}_E/\dot{V}CO_2$) and end-tidal partial pressure of CO_2 (PCO_2) is stable[17]. RCP was determined as the point where end-tidal PCO_2 began to fall after a period of isocapnic buffering[18]. This point was confirmed by examining $\dot{V}_E/\dot{V}CO_2$ plotted against $\dot{V}O_2$ and by identifying the second breakpoint in the $\dot{V}_E$-to-$\dot{V}O_2$ relation. Maximal cadence at the slide board (CAD_{max}) was defined as the maximal number of push-offs per minute reached during the slide board test. If the final stage was not completed, the CAD_{max} was calculated according to the following equation adapted from Kuipers et al.[19]: $CADmax = CADf + t/s \times 3$, where $CADf$ is the cadence of the final stage completed, t the uncompleted stage time (in s), s the stage duration (= 60 s) and 3 the cadence increment per stage. The same equation was used to calculate maximal speed at the end of the treadmill skating test, using speed values instead of cadence and 2 (increments of 2 $km \cdot h^{-1}$) instead of 3.

Statistical Analysis

Data are presented as means ± SD. Normality of the data was assessed using the Shapiro-Wilk test. Two-tailed pairwise t-tests were performed to compare variables obtained from a maximal incremental test performed on a skating treadmill with variables obtained from a maximal incremental test performed on a slide board. Effect sizes (ES) of each pair of comparisons were categorized as small (ES < 0.20), moderate (ES > 0.20 - 0.8) or large effects (ES > 0.8)[20]. Pearson correlation coefficients between the variables obtained from the treadmill and slide board protocols and between the skaters' best time on 1500 m distance on ice and GET, RCP and $\dot{V}O_{2max}$. The following criteria were adopted for interpreting the magnitude of correlation between variables: <0.10, trivial; 0.11–0.30, small; 0.31–0.50, moderate; 0.51–0.70, large; 0.71–0.90, very large; and 0.91–1.00, almost perfect[21]. A level of magnitude above very large is warranted for correlations, because a value of 0.9 is described as a threshold for validity[21]. Typical error of measurement, expressed as absolute values and as coefficient of variation ($TEM_{CV\%}$), were determined using the techniques described by Hopkins[21]. Statistical analysis was conducted using GraphPad Prism (GraphPad Prism Software Inc. v. 5.0, San Diego, CA) and Statistical Package for Social Sciences (SPSS Inc. v.17.0, Chicago, IL). The statistical significance was accepted when $p<0.05$.

Results

Maximal physiological comparisons indices and correlation are reported in table 1. No statistically significant differences were found for $\dot{V}O_{2max}$ and HR_{max} measured when skating on a treadmill versus skating on a slide board. $[La]_{peak}$, RER_{max} and V_{Emax} were significantly higher when skating on a treadmill. Significant correlations were obtained for $\dot{V}O_{2max}$ (r = 0.94), HR_{max} (r = 0.87) and $\dot{V}_{Emax}$ (r = 0.87) (Table 1).

Maximal cadence (60 ± 4.8 ppm) and maximal speed (30.7 ± 4.1 km·h^{-1}) values were significantly correlated (r = 0.77).

Table 2 depicts physiological responses associated to the GET and RCP during the maximal incremental skating tests on a treadmill and on a slide board. The $\dot{V}O_2$, percentage of $\dot{V}O_{2max}$ (%$\dot{V}O_{2max}$), HR, and $\dot{V}_E$ values associated with GET and RCP were not significant different between the skating on a treadmill and on a slide board. RER values at GET and RCP were significantly smaller on a slide board skating. Most of the variables at GET and RCP obtained on a treadmill and on a slide board skating were significantly correlated, except %$\dot{V}O_{2max}$ at RCP and RER at GET and RCP intensities.

Very large correlation was found for $\dot{V}O_{2max}$ attained during treadmill and slide board skating (Figure 3), and very similar $\dot{V}O_2$ responses were obtained throughout the two exercise modalities (Figure 4). Very large correlations were found between the athletes' personal best time on 1500 m distance (2.13 ± 0.14 min) and $\dot{V}O_{2max}$ in L·min^{-1} (r = 0.85; 0.91), GET (r = 0.81; 0,80) and RCP (r = 0.88; 0,89) found during skating on a treadmill and on a slide board, respectively.

Discussion

This study aimed to compare physiological responses during a maximal incremental skating test on a treadmill and on a slide board. The main finding was that the $\dot{V}O_{2max}$ and $\dot{V}O_2$ associated with GET and RCP were not statistically different and significantly correlated between both exercise modalities, suggesting that skating on a slide board is a good representation of the physiological responses obtained during treadmill skating.

To deliver high power outputs, both aerobic and anaerobic resources are crucial, although their contribution varies over the different distances[22]. The averaged $\dot{V}O_{2max}$ values found on a slide board were similar and correlated to those obtained on a skating treadmill (Table 1). These results are similar to the $\dot{V}O_{2max}$ found during two different slide board skating protocols performed by speed skaters of similar age and training volume[13]. It is known that $\dot{V}O_{2max}$ values reported during skating are around 7-10% lower than those during cycling, likely due to the physiological consequences of the skating position[2,3,7]. Consequently, the relatively low $\dot{V}O_{2max}$ values reported in the present study are not surprising, considering the low $\dot{V}O_{2max}$ values previously reported in the literature for elite speed skaters tested on ice (53.9 mL·kg^{-1}·min^{-1} for males) and on a cycle ergometer (57.2–62.0 and 52.2–54.9 mL·kg^{-1}·min^{-1} for males and females, respectively)[1,6,8]. Moreover, the skaters evaluated in the present study were not elite athletes, mainly females (8/12) and most of them short distance specialists (under 3000 m).

The average $\dot{V}O_2$ responses during the two protocols were virtually the same (Figure 4A and B), indicating a close pattern of physiological demand. A relatively large plateau in $\dot{V}O_2$ versus workload relationship was observed for most of the tests. Foster et al.[23] pointed out to a remarkable ability of the skaters to rapidly attain and sustain maximal level of $\dot{V}O_2$ for the duration of the time trial distance. The high anaerobic capacity of speed skaters, one of the highest recorded by any group of athletes[24], could explain the evident $\dot{V}O_2$ leveling off on the last stages of the incremental skating protocols. However, since anaerobic capacity was not specifically measured during the skating protocols, this speculation still needs to be addressed.

The correlation found between $\dot{V}O_{2max}$ expressed in L·min^{-1} values attained during skating on a slide board and on a treadmill (r=0.94) was 'almost perfect' according to Hopkins[21] criteria (Figure 3). A level of magnitude above very large (0.90) is warranted for concurrent validity correlations[21]. There are no published studies examining the validity of a maximal incremental skating test on a slide board. Leone et al[25] and Petrella et al[26] found correlations of 0.69 – 0.76 when comparing $\dot{V}O_{2max}$ during ice hockey aerobic field tests with similar running field tests as the criterion measure. The lower correlations found by the authors can be related to the different exercise modality adopted as a criterion test. The difference in correlation between $\dot{V}O_{2max}$ expressed in $L \cdot min^{-1}$ and $mL \cdot kg^{-1} \cdot min^{-1}$ can be related to difference in data homogeneity. As the homogeneity of the group increases, the variance decreases and the magnitude of the correlation coefficient tends to decrease. Therefore, since $\dot{V}O_{2max}$ group values are less heterogeneous when expressed in $mL \cdot kg^{-1} \cdot min^{-1}$, this could partially explain the lower correlation for this index ($r = 0.84$).

In addition to the similar $\dot{V}O_2$ responses and very large correlation observed for $\dot{V}O_{2max}$ attained when skating on a treadmill and on a slide board, these two conditions resulted in a low between test variability of 5%. This value is similar to the one reported using supramaximal verification bouts versus graded maximal test to elicit $\dot{V}O_{2max}$ (4.3%) reported by Hawkins et al.[27]. Thus, the slide board protocol seems to provide valid and consistent values of $\dot{V}O_{2max}$ when considering account individual subject variations.

Very large correlations ($r > 0.80$) were found between the athletes' best time of the season in 1500 m distance and the GET ($r = 0.81$), RCP ($r = 0.89$) and $\dot{V}O_{2max}$ ($r = 0.91$) measured on the slide board further support the validity of those indices to predict and evaluate speed skating performance on ice. This contrasts with the lack of relationship shown between aerobic and anaerobic indices obtained during a cycling test and skating performance[22], supporting the notion that cycling tests are not ideal to evaluate seasonal changes in performance of highly trained skating athletes. Yet one must acknowledge that the $\dot{V}O_{2max}$ was more homogeneous in van Ingen Schenau et al. [22].

Despite the similarities found between treadmill and slide board skating, $\dot{V}_{Emax}$, RER_{max} and $[La]_{peak}$ were significantly smaller during the slide board test and ES were moderate to large, pointing out for meaningful differences (Table 1). These findings were unexpected and might be related to slight differences in body posture adopted on the slide board, since at smaller knee and/or hip angles the ventilatory response can be altered because of mechanical limitations during skating[12, 28]. De Boer et al.[28] found greater RER and $\dot{V}_E$ maximal values during inline compared to on ice maximal skating tests, with no significant differences in $\dot{V}O_{2max}$, and a more upright posture during inline skating. Differences in RER could be related to decreased $\dot{V}_E$, as suggested by Rundell and Pripstein[12], or could be linked to a decreased $[La]_{peak}$ possibly caused by a more pronounced blood flow occlusion and the associated decrease in lactate efflux[29].

$\dot{V}O_2$ values at GET and RCP were similar and well correlated (Table 2) in both conditions, and represented ~ 67 and ~ 92% of $\dot{V}O_{2max}$ obtained during the skating tests. Piucco et al.[13] reported similar $\%\dot{V}O_2$ values at the second ventilatory threshold, i.e. RCP, during two different skating protocols on slide board, when investigating skaters with similar profile. However, these values are higher than those reported for GET (61%) and RCP (80%) during cycling[16]. Boone et al.[30] found RCP intensities at ~ 87% of VO_{2max} during cycling, this value being influenced by the aerobic fitness level i.e. trained individuals showing greater percent RCP. Therefore, a high endurance capacity of the speed skaters[1,7], combined with the idea that true maximal values might not have been achieved due to the blood flow restriction, could result the larger percent RCP associated to $\dot{V}O_{2max}$ observed in this study. It is important to note that this is the first study investigating GET and RCP during a specific skating protocol. An effective evaluation of sport performance needs to reproduce the physiological responses during exercise, which are dependent on the characteristics of the movement pattern, such as posture, muscle recruitment and mode of contraction utilized during exercise[31, 32]. The unique crouched skating technique (i.e. small knee- and trunk angle) leads to an increase deoxygenation of the working muscles. Due to the reduced blood flow associated with the crouched skating posture, an increased recruitment of the fast-twitch fibres may occur[33]. Consequently, although commonly used[7, 22], cycling tests do not offer optimal conditions to evaluate physiological variables associated with performance in speed skating. Therefore, the similar values for skating intensity threshold observed during treadmill skating and slide board strengthens the validity of skating on a slide board as a good model to represent the physiological profile of skating.

The main limitation of the slide board protocol is that it cannot replicate the effects of cornering. Technical aspects of cornering seem to have an impact on oxygenation, affecting processes related to the regulation of exercise intensity such as fatigue and recovery[34]. Also, aerodynamics, drafting effects, and optic flow perception are not important in treadmill and slide board tests, while they are important determinants of skating performance[33]. Keeping the skating treadmill on a level grade during the maximal treadmill skating test is another potential limitation. Skating on a level grade can be technically too difficult and might lead to the test finishing without exerting the highest levels of power due to lack of resistance and small friction. This might be especially true for recreational skaters, hockey players, cross-country skaters and amateur speed skaters. In this case, changing the treadmill inclination or using additional methods to increase skating resistance during the test is recommended. Further comparison between slide board test and field test results are necessary to strengthen the validity of the results. However, the strong correlations found between the maximal and submaximal $\dot{V}O_2$ data during skating on a slide board and skating performance on ice suggest that actual determinants of performance can be assessed using the slide board test.

Practical Applications

The $\dot{V}O_2$, HR and $\dot{V}_E$ profile of skating on a slide board is similar to skating on a treadmill. Also, outcomes of the skating test on a slide board skating relate to actual skating performance. Therefore, speed skating coaches can use the slide board test as a valid and specific method to establish maximal physiological indices and exercise intensity boundaries. The accessibility of the slide board makes this tool of interest when considering repetitive testing in different locations (i.e. training camps) during the season.

Conclusions

In conclusion, the results of the present study support the hypothesis that skating on a slide board mimics some important physiological responses obtained during treadmill skating. The slide board test, a simple and affordable approach in terms of accessibility and cost, was capable to appropriately assess maximal and submaximal parameters that determine endurance performance, such as $\dot{V}O_{2max}$ and aerobic/anaerobic intensity thresholds during skating. The slide board test is valid (correlation coefficients above 0.9) to determine $\dot{V}O_{2max}$ and $\dot{V}O_2$ at the thresholds. However, caution should be taken when using HR and blood lactate data from slide board incremental test for training prescription. Maximal and submaximal aerobic indices during slide board skating test were correlated with skating performance on ice (i.e., best time on 1500 m skating distance). Thus, the slide board test is a specific and practical test that can be used to evaluate speed skating performance, prescribe exercise training intensities and monitor adaptations due to training program.

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Table 1 - The mean ± standard deviation values, Pearson's product moment correlation coefficients (r), effect size (ES) and the relative typical error of measured ($TEM_{CV\%}$) between maximal variables obtained when skating on a treadmill skating and on a slide board.

	Treadmill	Slide board	r	ES	TEM $_{CV\%}$
$\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	3.04 ± 0.54	3.05 ± 0.65	0.94 [b]	0.002	5.3
$\dot{V}O_{2max}$($mL \cdot kg^{-1} \cdot min^{-1}$)	46.7 ± 4.4	46.4 ± 6.1	0.80 [b]	0.05	5.5
HR_{max} (bpm)	195 ± 6	196 ± 10	0.87 [b]	0.05	2.0
RER_{max}	1.3 ± 0.1	1.2 ± 0.1 [a]	0.30	1.65	5.1
$\dot{V}_{Emax}$ ($L \cdot min^{-1}$)	148.5 ± 28.3	138.7 ± 22.4 [a]	0.87 [b]	0.41	6.6
$[La]_{peak}$ ($mmol \cdot L^{-1}$)	12.2 ± 2.3	9.3 ± 2.3[a]	0.11	1.28	20.3

a - Significant difference ($p < 0.05$); b - Significant correlation ($p < 0.05$). $\dot{V}O_{2max}$ = maximal oxygen uptake; HR_{max} = maximal heart hate; RER_{max} = maximal respiratory exchange ratio; $\dot{V}_{Emax}$ = maximal ventilation; $[La]_{peak}$ = peak blood lactate concentration.

Table 2 - The mean ± standard deviation values, Pearson's product moment correlation coefficients (r), effect size (ES) and the relative typical error of measured ($TEM_{CV\%}$) between submaximal variables (GET and RCP) obtained when skating on a treadmill and on a slide board .

GET	**Treadmill**	**Slide board**	**r**	**ES**	**$TEM_{CV\%}$**
$\dot{V}O_2$ ($L \cdot min^{-1}$)	2.02 ± 0.37	2.04 ± 0.36	0.91^{b}	0.06	5.5
$\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	30.9 ± 3.2	31.4 ± 4.1	0.75^{b}	0.12	6.1
% $\dot{V}O_{2max}$	66.3 ± 4	67.7 ± 7.1	0.62^{b}	0.24	6.5
HR (bpm)	153 ± 14	150 ± 12	0.90^{b}	0.29	3.1
RER	0.92 ± 0.06	0.88 ± 0.04^{a}	0.50	0.78	7.7
$\dot{V}_E$ ($L \cdot min^{-1}$)	59.8 ± 11.8	57.0 ± 10.7	0.85^{b}	0.25	7.4
RCP	**Treadmill**	**Slide board**	**r**	**ES**	**$TEM_{CV\%}$**
$\dot{V}O_2$ ($L \cdot min^{-1}$)	2.78 ± 0.53	2.81 ± 0.56	0.97^{b}	0.05	3.0
$\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	42.5 ± 4.4	42.9 ± 4.8	0.92^{b}	0.09	3.0
% $\dot{V}O_{2max}$	91.1 ± 3.3	92.4 ± 2.1	0.37	0.50	3.3
HR (bpm)	178 ± 9	178 ± 6	0.85^{b}	0.04	2.0
RER	1.05 ± 0.08	0.99 ± 0.05^{a}	0.50	0.92	4.3
$\dot{V}_E$ ($L \cdot min^{-1}$)	96.5 ± 19.0	92.1 ± 12.7	0.90^{b}	0.27	7.2

a - Significant difference ($p < 0.05$); b - Significant correlation ($p < 0.05$). $\dot{V}O_2$ = oxygen uptake; % $\dot{V}O_{2max}$ = percentage of $\dot{V}O_{2max;}$ HR= heart hate; RER = respiratory exchange ratio; $\dot{V}_E$ = ventilation. GET = gas exchange threshold; RCP = respiratory compensation point.

Figure 1. Slide board set up. 1- Photo emitter; 2- Photo receptor.

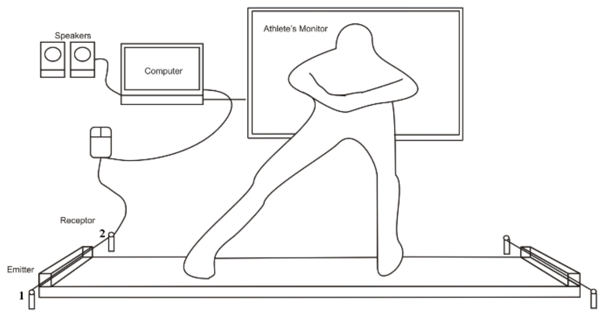


Figure 2. Incremental skating protocol to exhaustion on a treadmill (A) and on a slide board (B). Increase in cadence on the slide board is represented by numbers of push-offs per minute (ppm).

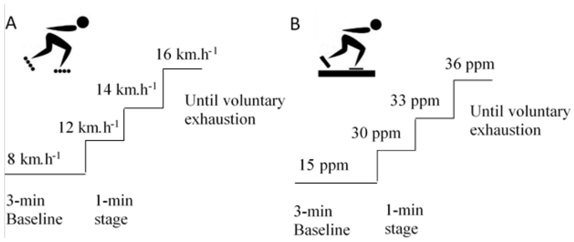


Figure 3. Correlation (95% CI) between $\dot{V}O_{2max}$ attained on a treadmill and on a slide board.

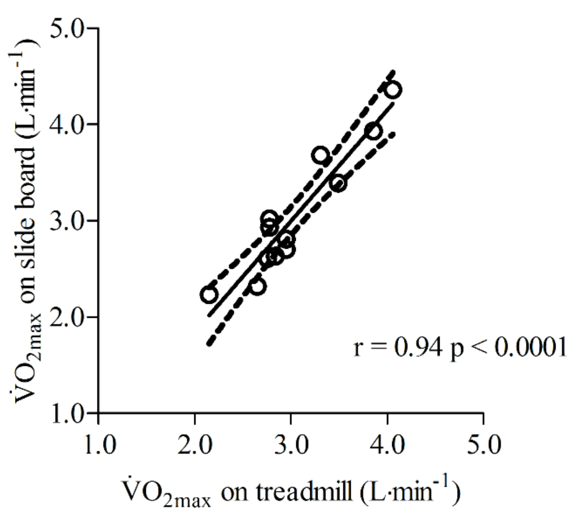
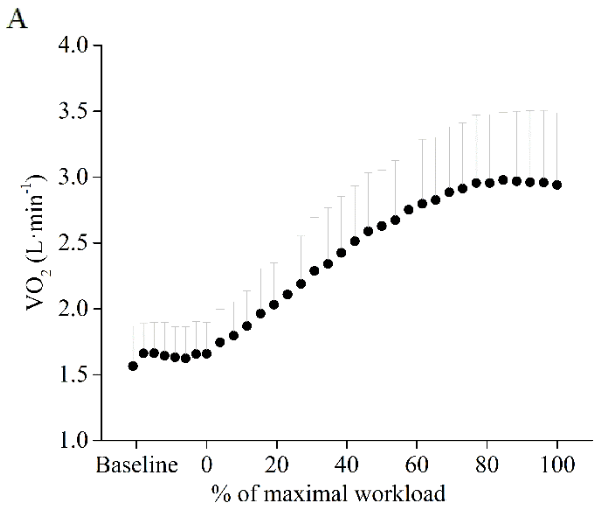
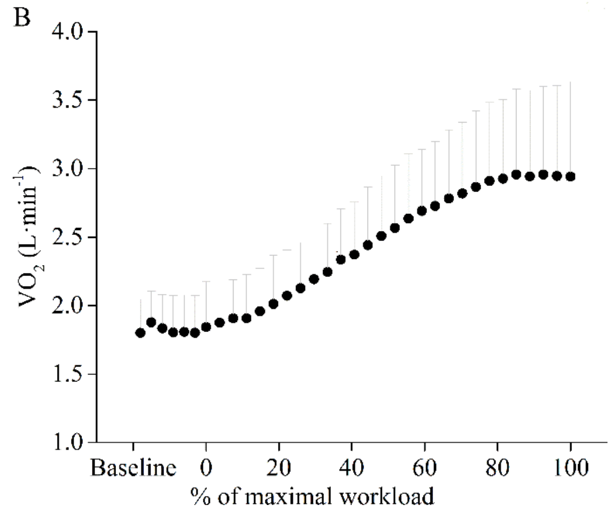


Figure 4. Average $\dot{V}O_2$ response during skating on a treadmill (panel A) and on a slide board (panel B).


A
4.0
3.5
3.0
2.5
2.0
1.5
1.0
VO2 (L·min-1)
Baseline 0 20 40 60 80 100
% of maximal workload


B
4.0
3.5
3.0
2.5
2.0
1.5
1.0
VO2 (L·min-1)
Baseline 0 20 40 60 80 100
% of maximal workload