Journal of Exercise Science & Fitness 16 (2018) 32–36

Contents lists available at ScienceDirect

Journal of Exercise Science & Fitness

journal homepage: www.elsevier.com/locate/jesf

The relationship between ventilatory threshold and repeated-sprint ability in competitive male ice hockey players

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A R T I C L E I N F O

Article history:
Received 13 June 2017
Received in revised form
18 January 2018
Accepted 9 March 2018

Keywords:
Athletes
Aerobic capacity
Fatigue
Sprint decrement

A B S T R A C T

Background/objective: The relationship between ventilatory threshold (VT1, VT2) and repeated-sprint ability (RSA) in competitive male ice hockey players was investigated.
Methods: Forty-three male ice hockey players aged 18–23 years competing in NCAA Division I, NCAA Division III, and Junior A level participated. Participants performed an incremental graded exercise test on a skate treadmill to determine $\dot{V}O_{2peak}$, VT1, and VT2 using MedGraphics Breezesuit™ software (v-slope). Participants performed an on-ice repeated shift (RSA) test consisting of 8-maximal skating bouts, lasting approximately 25 s and interspersed with 90 s of passive recovery, to determine first gate, second gate, and total sprint decrement ($\%_{dec}$). Pearson product-moment correlations and multiple regressions were used to assess relationships between ventilatory threshold variables (VT1, VT2, Stage at VT1, and Stage at VT2) and RSA (first gate, second gate, and total course decrement).
Results: Stage at VT2 was the only variable substantially correlated with first gate ($r = -0.35$; $P < 0.05$), second gate ($r = -0.58$; $P < 0.001$) and total course decrement ($r = -0.42$; $P < 0.05$).
Conclusion: The results of this study demonstrated that VT is substantially associated with RSA, and VT2 is more strongly correlated with RSA than $\dot{V}O_{2peak}$. This study suggests that longer duration high-intensity interval training at intensities that increase workrate at VT2 may lead to possible improvements in RSA.

Introduction

Ice hockey performance involves intermittent, high-intensity, complex movements requiring a combination of individual skills, team play, tactics, strategies, and motivational aspects.[1–3] Despite the complex nature of the sport, enhanced physical fitness would likely improve both individual and team performances. Repeated-sprint ability (RSA) is one such physical ability involved in ice hockey. Due to heavy reliance on anaerobic metabolism during repeated sprint based shifts last 30–80 s (69% anaerobic glycolysis) followed by relatively short recovery periods (31% aerobic metabolism),[4] the ability of a player to repeatedly withstand fatigue at high work intensities will lead to a competitive advantage.[5] Several authors have examined the relationship between RSA (operationalized as percent decrement or fatigue index) and aerobic fitness (operationalized as $\dot{V}O_{2max}$ or $\dot{V}O_{2peak}$) with varying results ranging from strong negative relationships to no detectable association.[5–13] While substantial relationships have been reported between RSA and $\dot{V}O_{2peak}$,[5,7,8,11–13] the relationship between RSA and other components of aerobic fitness (e.g., lactate and ventilatory threshold) are not well understood.[14]

While $\dot{V}O_{2max}$ or $\dot{V}O_{2peak}$ is considered the "gold standard" measure of aerobic fitness,[15] the lactate threshold (LT: the highest sustainable work rate where lactate production and clearance is at equilibrium),[16] and its associated measurement of ventilatory threshold (VT1/VT2: the points at which ventilation changes as a shift in lactate production occurs as work rate increases)[17,18] may be a stronger correlate of RSA than $\dot{V}O_{2peak}$.[14,15] In soccer, lactate threshold is more strongly correlated with RSA than is $\dot{V}O_{2peak}$

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https://doi.org/10.1016/j.jesf.2018.03.003
1728-869X/

($r = -0.54$ vs. $r = -0.39$, respectively).[14] These findings suggest that increased aerobic capacity at higher sustainable work rates may improve RSA by enhancing local and systemic metabolic byproduct clearance and increased aerobic energy production during repeated sprint bouts.[7,12] It may therefore be more important to develop LT than $\dot{V}O_{2peak}$ for RSA performance among intermittent high intensity sport athletes.[9] Although there are comparable physiological aspects between the both highly anaerobic and aerobic sports of soccer and ice hockey.[4,19] There still exists large physiological and game play variations between them. Such as game time length, physiological movement mechanics, and the intermittent play and intermission recovery time.[4]

If LT exhibits a stronger relationship to RSA than $\dot{V}O_{2peak}$, then LT and possibly its associated measurement VT, may be a more useful construct for coaches, practitioners, and scientists interested in evaluating training parameters that influence RSA sport performance. Training practices to optimise improvement in LT and VT are different to those targeting $\dot{V}O_{2peak}$.[20] Furthermore, LT and VT appear to demonstrate greater percent change and continue to improve with training for a longer duration than $\dot{V}O_{2peak}$.[20–24] This makes LT and/or VT an attractive candidate for athletic evaluation and programming. To date, we are unaware of any investigations looking at LT or VT in competitive ice hockey players. Population-specific evidence is needed to determine if this relationship exists in hockey athletes due to the apparent differences between soccer and ice hockey, along with the present lack of current research. The primary aim of this study was to quantify the association between VT and RSA in competitive male ice hockey players. The secondary aim was to determine if VT was a stronger predictor of RSA than $\dot{V}O_{2peak}$. It was hypothesised that VT would be substantially related to RSA and more strongly associated than $\dot{V}O_{2peak}$ due to the physiological mechanisms that allow a greater sustainable workrate at VT.

Methods

Participants

Forty-three, well-trained, male ice hockey players (mean ± SD: age 20.0 ± 1.4 years; height 182.5 ± 6.3 cm; body mass 84.8 ± 6.5 kg; percent body fat 11.8 ± 2.8%; relative $\dot{V}O_{2peak}$ 55.0 ± 4.5 mL/kg/min) competing at the Division I, Division III, and Junior A level participated in this study. All participants were recruited via convenience from Minneapolis, Minnesota, USA, and provided informed consent. The Institutional Review Boards of the University of Minnesota and University of North Dakota approved this study. Participants were excluded if they were absent from on-ice skating over the previous 30 days due to injury and/or if they identified their position as goaltender.

Study design

A cross-sectional study design was used to determine the relationship between VT (VT1 & VT2) and RSA (percent decrement of first gate, second gate, and total course) during an on-ice repeated shift test in competitive ice hockey players. At the start of offseason training, athletes had their anthropometric characteristics, aerobic fitness, and on-ice repeated shift performance assessed in three separate sessions, spaced at least 48 h apart, over a 10-day period. Participants were instructed to refrain from caffeine, tobacco, and alcohol 12 h prior, and to avoid heavy exercise 24 h prior, to testing.

Anthropometric assessment

Height (cm) and body mass (kg) were recorded using a stadiometer and the Detecto Mechanical weight scale (Webb City, MO, USA), respectively. Body density was assessed by hydrostatic weighing using the protocol described by described by Graves, Kanaley, Garzarella, & Pollock.[25] Percent body fat was estimated using Exertech Body Densitometry Systems software (Dresbach, MN, USA), which uses the Goldman (1959) equation to estimate residual lung volume and the Brožek (1963) equation to estimate percent body fat (test-retest reliability: $r = 0.95$).[25]

Determination of aerobic fitness

A sport-specific graded exercise test was performed on a synthetic ice skate treadmill (Frappier™ Acceleration, Minneapolis, MN, USA; The Blade™ Woodway, Waukesha, WI, USA) to determine $\dot{V}O_{2peak}$, VT, and final stage completed (a work rate marker of $\dot{V}O_{2peak}$). The protocol used was previously described by Peterson et al.[5] The Ultima CPX (Medgraphics, St. Paul, MN, USA) was used to measure breath-by-breath respiratory gas volume and concentration using Breezesuite™ software (Medgraphics, St. Paul, MN, USA). The Ultima CPX compares favorably with the Douglas bag technique (average error <3%) and exhibits good test-retest reliability (coefficient of variation <5%) for both VO_2 and VCO_2 measurement.[26] The skate treadmill protocol was developed by Koepp & Janot[27] to accurately determine $\dot{V}O_{2peak}$ of ice hockey players. During this protocol, participants began skating at a 2% grade and a speed of 6.5 mph (10.5 km/h).[27] Treadmill speed then increased by 0.5 mph (0.8 km/h) every minute thereafter until a maximum speed of 10 mph (16.1 km/h) was achieved at the 8-min mark, with 1% grade increases every minute thereafter until volitional exhaustion.

Determination of ventilatory threshold

Both ventilatory threshold (delinated as VT1) and respritory compensation, commonly known as a second ventilatory threshold (delinated as VT2), points were determined by Breezesuite™ software (Medgraphics, St. Paul, MN, USA) without manual adjustment from data collected during the graded exercise test. Breezesuite™ software's VT detection program utilizes an iterative regression and analysis of the slope $\dot{V}CO_2$ vs. $\dot{V}O_2$ to determine where CO_2 production begins to increase disproportionately to the O_2 consumption (V-Slope method). This method correlates very strongly with the lactic acidosis threshold ($r = 0.86$) and is a reproducible ($r = 0.71$) and useful non-invasive measure for the determination of VT.[28] The same method is used to identify a second inflection point, occurring after VT1, between these two parameters to identify the respritory compensation point (VT2). VT1 and VT2 were reported as oxygen consumption at VT1 and VT2 as indicated by Breezesuite™ software. The treadmill stage (work rate) was also recorded for each threshold and labeled stage at VT1 and VT2.

On-ice repeated shift test

The on-ice repeated shift test was previously described by Peterson et al.,[5] which was designed to simulate on-ice work demands experienced during competition. The protocol was primarily designed based on data collected from the National Hockey League.[5] Participants completed eight maximal skating bouts through a fixed distance course, which took approximately 25 s to complete, with 90 s of passive recovery in between bouts. Participants performed this test in full ice hockey gear whilst holding their hockey stick. Three separate timing gates were used to assess first gate (first half: roughly the 0–10 s mark), second gate (second half: roughly the 11–25 s mark), and total fatigue decrement (total course time). Time to complete the course was measured using a TC