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Acute effect of mechanical self-induced multi-bar massage rolling of quadriceps muscle in young elite speed skaters on performance and recovery

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Abstract: Objectives: The main purpose of the present study was to investigate the acute effects of myofascial massage on endurance performance and recovery using a novel designed mechanical self-induced multi-bar massage rolling machine. Methods: a randomized crossover, repeated measure design was used. Four male and four female, national levelled, junior and neo-senior, speed skaters underwent a ten minutes myofascial quadriceps massage pre- and fifteen minutes post- a stepwise incremental cycling-test to exhaustion followed by a Wingate performance-test. The massage was used in one out of two laboratory testing-days. Time to exhaustion, peak oxygen uptake (VO2peak), blood lactate concentration ([La$^-$]b) during 30 min of recovery, and peak- and mean- power during the consecutive Wingate test were recorded. Results: Massage resulted in higher [La$^-$]b at exhaustion and a larger [La$^-$]b clearance after 10 min to post exhaustion test (both $P < 0.05$), a tendency for a positive effect on Wingate peak-power ($P = 0.084$; $d = 0.71$), whereas no marked differences were observed on vO_{2peak}, time to exhaustion and Wingate mean-power. Conclusion: Despite indications for potential benefit ([La$^-$]b and Wingate peak-power results), massage gave no marked performance improvements. However, no indications of negative effects were observed. Hence, using the mechanical self-induced multi-bar massage roller does not seem to be harmful. Future studies should examine the long-term effects of massage on performance and recovery.

Keywords: vO_{2peak}; blood lactate; Wingate

1. Introduction

Speed skating is the oldest organized winter sport and the fastest way in which humans can propel on level ground without external power or gears [1]. Since the International Skating Union

(ISU) was stablished in 1892, skaters have raced against each other in pairs, striving to finish the traditional distances 500, 1000, 1500, 3000, 5000 and 10000 m in the shortest time possible [1]. However, both the prestigious World Championships in all-round (500, 5000, 1500 and 10000 m) and in sprint (500 and 1000 m) are performed over two consecutive days, with (according to ISU-rule number 246) a minimum rest period of 30 min between races. Such a rule indicates that recovery between races is imperative to performance. Research has shown a ~6% reduction in mean power output after 6 min of recovery between two 30 s of sprint cycling [2], a reduced cycling performance with 20 min recovery between two 5 km (~380 s) time-trials [3], a decrease in accumulated oxygen deficit between two time-trials (~205 s) on a roller-skiing treadmill separated by 25 min recovery [4], and a reduced running performance with 30 min of recovery between two 800 m (~145 s) time-trials [5].

The prestigious 1500 m distance (world record of 101.02 and 110.85 s for men and women, respectively) require about 45% anaerobe energy from the speed skaters [6]. This is partly due to the low quasi-static posture the skaters maintain. The low posture includes small knee angles (to reduce the aerodynamic drag), needed to achieve high speed. However, this posture also limits the blood flow to the quadriceps muscles [7] and reduces the vO2peak while skating [8], which makes anaerobic capacity crucial for speed skating performance [9]. Furthermore, the amount of ATP stored in the human body (at any giving time) have been reported to be between ~80 – 100 g and a reduction in ATP stores triggers the phosphagen system to maintain the concentration of ATP by activating creatine kinase reaction [10]. During continues high intensity exercise, the breakdown of carbohydrate to resynthesize ATP occur through a process called glycolysis [10, 11]. Pyruvate is the result of glycolysis and convert into lactate when ATP resynthesizes occurs at a very fast rate [10, 11]. Lactate measures has been used as a recovery marker in training and between competitions [12]. Research indicates that measuring lactate clearance between successive high intensity competitions that depends on glucose as the primary source of ATP resynthesizes could be an indication of the athlete readiness for the next event [3, 5].

Several modalities has been introduced to speed up recovery between training and competition sessions such as massage [13], active recovery [14], cryotherapy [15], contrast temperature water immersion [16], hyperbaric oxygen therapy [17], nonsteroidal anti-inflammatory drugs [18], compression garments [19], stretching [20] and foam rolling [21, 22]. Due to its practicality, athletes' self- myofascial release using rollers for the purposes of rehabilitation and enhancing mobility [23], as a substitute for massage, has been widely observed in the past few years. Among others, several studies have examined the effect of self- myofascial release on joint range of motion [24, 25], recovery from exercise-induced muscle damage [21], recovery between high intensity bouts [5, 26], recovery after competition [22] and performance if applied pre-competition [27]. The main differences between the reported self- myofascial release tools can be summarized in two stances; (i) applied pressure and; (ii) rolling cadence. E.g., using tennis balls and foam rollers, partial body weight or body weight to determine the pressure applied, and the subject control of rolling cadence [5, 28]. Using the self-administrated roller massage-stick, the subject apply force and control the rolling cadence on the muscle tissue [29]. In contrast, a consistent pressure (i.e., force applied on the muscles using weight plates) combined with a fixed rolling cadence have been reported for the mechanical-roller massage bar [25, 30]. Furthermore, the effect of the mechanical-roller massage bar on joint range of motion, maximum voluntary contraction, electromyography activity during exercise and pain has been explored [25, 30]. However, to date, the effect of mechanical self-induced (where athletes using their body weight to apply force on a fixed rolling cadence) multi-bar massage roller on recovery and performance has yet to be investigated. Therefore, the purpose of the present study was to investigate the effects of mechanical self-induced multi-bar massage rolling of quadriceps muscle on performance and recovery in young elite speed skaters.

2. Materials and Methods

2.1. Study design and participants

A random crossover, repeated measure design was implemented to investigate the effects of a novel designed mechanical self-induced multi-bar massage roller on athlete's recovery and performance. In a randomised order, participants were provided with 10 min massage pre and 15 min post a cycling test to exhaustion on one of two testing days where the second day was a control day. Peak oxygen uptake ($\dot{V}O_{2peak}$), respiratory exchange ratio (RER), blood lactate concentration ($[La^-]_b$) and measures of performance were collected throughout the testing procedure (Figure 1).

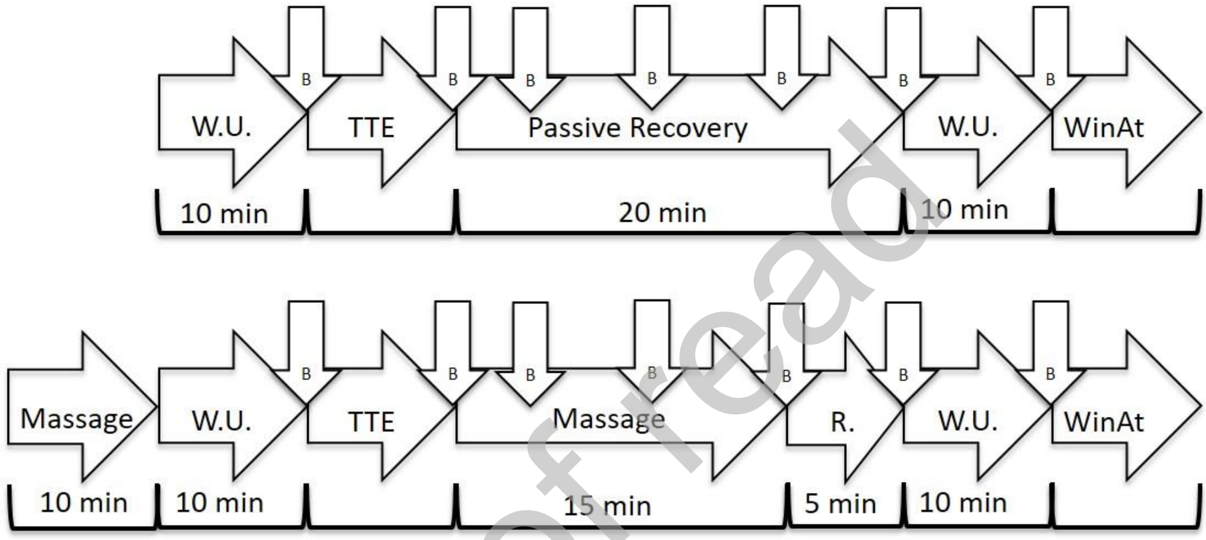

Figure 1. Testing procedure with (upper figure) and without (lower figure) massage. B = [La⁻]b test time; W.U. = Warm up; TTE = Test to exhaustion; R. = Rest; and WinAt = Wingate Anaerobic test.

2.2. Participants

Eight junior and neo-senior speed skaters aged 18.6 ± 1.3 years (mean ± SD), body mass 63.8 ± 6.6 kg and height 171.5 ± 7.9 cm, volunteered to participate in the present study. All skaters were qualified for Norwegian championships and consisted of four males (age: 18.5 ± 1.9 years, body mass: 67.9 ± 4.7 kg, height: 178.5 ± 2.7 cm) and four females (age: 18.8 ± 0.5 years, body mass: 59.7 ± 6.1 kg, height: 164.5 ± 1.6 cm). In addition to ice- and roller-skating, a normal training year for speed skaters include a lot of cycling, weights- and power training and different dry-land exercises in skating position without skates. In addition to 3 – 6 individual training sessions per week, the participants trained together 4 – 6 sessions per week from May until mid-March. According to their coaches' training plan, athletes are required to do a total of 685 hours of training and racing per year. All participants were healthy at the time of testing with none reporting any ongoing injuries affecting their cycling performance. Written informed consent was obtained from all subjects after a verbal and written explanation of the experimental design and potential risks associated with participating in the study. The study was conducted according to the Helsinki Declaration and the Norwegian National Committees for Research Ethics. This study is registered at the Norwegian centre for research data (id: 58950/3/LT) and the current research information system in Norway under project id: 568684.

2.3. Procedure

One month prior to testing, participants performed a stepwise incremental lactate threshold test to determine the participants heart rate (HR) and external load representing 4 mmol/l of $[La^-]_b$. These results determined the workload at warm up and at the first stage of the test to exhaustion during the official testing days. The test was conducted on a stationary Stage SC3 bike (Stages Cycling, Boulder, Colorado, USA), using a fixed (90 rpm) cadence. The test leader registered workload (Watts), HR, rate of perceived exertion (Borg scale) and $[La^-]_b$ every fifth minute and before the workload was manually increased by 25 watts. The test ended when the $[La^-]_b$ concentration reached above 4 mmol/l.

2.3.1. Anthropometric measurements and warm up.

In the first testing day, participants' height and weight were recorded using a wall mounted Seca stadiometer model 222 and Seca flat digital scale model 877, respectively (Seca Medical Measuring Systems and Scales, Hamburg, Germany). Then participants conducted a warmup consisting of 10 min cycling on an indoor Star Trac spinning bike (model: Spinner NXT 7090; STAR TRAC, California, USA). The first five, and last three minutes of the warmup were performed on a HR equals to 40 beats per minutes (BPM) subtracted from HR at lactate threshold. In between, two times 45 s with 15 s of recovery was conducted on a HR equals to lactate threshold. Immediately after warmup the participant's $[La^-]$b concentration was registered using Lactate Pro2 (LT-1730, ARKRAY Factory Inc, Kyoto, Japan) (Figure 1).

2.3.2. Test to exhaustion.

After warm up, the participant adjusted seat and handlebar of the electro-magnetic test-cycle ergometer (Lode Excalibur, Model: sport 925900; Lode BV, Groningen, Netherland) to fit their individual versatile position. Prior to test start, mask size was chosen to insure headspace correction and the Vyntus CPX gas analyzer (Model: versatile JAEGER; Vyaire medical, Hoechberg, Germany) was calibrated using the fully automated 2-point gas calibration of the O_2/CO_2, through a special Twin Tube sample line combined with a fresh air flush system [31]. Then test to exhaustion started using a continuous incremental test starting at 125 W for females and 200 W for males' athletes and increased by 25 W/min until exhaustion. Participants were instructed to maintain a pedalling rate of 90 rpm [32, 33] and the test was stopped if the rpm fell below 80 or when the participant could no longer continue. VO_{2peak} and RER were measured using the breath-by-breath method powered by Sentry Suite system throughout the test. The following criteria had to be met for the measures to be accepted; (i) VO_2 plateaued despite increased exercise intensity; (ii) RER > 1.1; and (iii) a post-exercise $[La^-]_b$ >9 $mmol \cdot L^{-1}$ [33, 34]. Time to exhaustion and $[La^-]_b$ were registered immediately after the test, and $[La^-]_b$ was further registered at 5, 10, 15 and 20 min (Figure 1).

2.3.3. Intervention.

To measure the acute effect of pre performance massage on test to exhaustion performance, participants started one of the testing days with a 10 min [35, 36] quadriceps muscle group massage using the Z-Roller mechanical self-induced multi-bar massager (Model: V.802; Zen Products, Jessheim, Norway) with a rolling speed of 7.36 m/min. According to the manufacture, the Z-Roller (Figure 2) intends to give both transverse and circular massage at the same time, which gives a feeling closer to regular massage. However, to be able to massage the quadriceps muscle group, the Z-mattress (Zen Products, Jessheim, Norway) was placed over the Z-Roller (Figure 3). The Z-mattress has an integrated air pump that allows participant to adapt the air pressure by lowering or raising the mattress, which permits the increase or decrease of their body weight pressure on the Z-roller. The participants laid face down on the mattress with the quadriceps muscle group placed on the Z-Roller (Figure 4). Furthermore, to measure the effect of post-performance massage (between competition recovery), participants started with a 15 min [3, 37, 38] quadriceps muscle group massage using the Z-Roller immediately after the test to exhaustion was completed. All measures were identical to the measures collected on the control test day, including time intervals (Figure 1).

Figure 2. Z-Roller mechanical self-induced multi-bar massage roller.

Figure 3. The Z-mattress placed over the Z-Roller.

Figure 4. Participant laid face down on the mattress with the quadriceps muscle group placed on the Z-Roller.

2.3.4. Wingate anaerobic cycle ergometer test.

The Wingate anaerobic 30 s cycling all out test has been shown to be a strong predictor for 1500 m speed skating performance, even for elite athletes at an individual level [9]. Further, to simulate the allowed minimum recovery (according to ISU-rule number 246), the participants had only 30 min between “test to exhaustion” and the Wingate anaerobic test. Participants were requested to perform a second 10 min warm up (as described earlier) prior to the 30 s Wingate test performance followed immediately with $[La^-]_b$ registration (Figure 1). To eliminate the generated power output before the test, the 30 s Wingate all out test was started from a stationary position with feet fixed to the pedals [9, 39]. When the test leader gave the start signal, the athlete started pedalling with maximal effort for 30 s against a constant braking torque of 0.8 Nm/kg for males and 0.77 Nm/kg for females [39, 40]. Pedal rate was registered for each second and peak power (Watt), relative peak power (watt/kg), average power (Watt), and rate of fatigue percentage were calculated using a combination of mean pedal rate and the product of braking torque.

2.4. Statistical Analysis

Data were transferred to a PC running Microsoft Windows 10 for further analyses. First, Shapiro-Wilk normality test was performed using GraphPad Prism version 6.00 for Windows (GraphPad Software, La Jolla, California, USA) on all the measured variables resulting in normally distributed data. Then, 2-way mixed intraclass correlation (ICC) reliability was performed using IBM SPSS Statistics for Windows, Version 25 (Armonk, NY: IBM Corp.) on all measured variables, and the results showed an ICC of > 0.93 with a $P < 0.01$. To assess differences in central tendencies (mean) between the test with massage and the test without massage, paired t-test was performed on each measured variable using GraphPad Prism. For better understanding of the differences [41], results were presented as mean standard error of the difference, 95% Confidence Interval (95% CI) with the effect size (Cohen *d*) calculated and defined as small when $d = 0.2 – 0.49$, medium when $d = 0.5 – 0.79$ and large when $d \geq 0.8$ [42]. The alpha level for statistical significance was set to $P \leq 0.05$ for all statistical examinations.

3. Results

3.1. The effect of pre exercise massage on performance to exhaustion.

All participants in this study met the criteria set for the cycle test to exhaustion, including plateaued VO_2, RER > 1.1 and a post-exercise $[La^-]_b > 9$ mmol·L−1 (Table 1). The results further showed that a 10 min pre warm-up rolling had a trivial effect on $_{V}O_{2Peak}$VO2peakVO2peak ($d < 0.2$; $P = 0.65$), and small effect on time to exhaustion ($d < 0.49$; $P = 0.555$) and RER ($d < 0.49$; $P = 0.462$; Table 1). Furthermore, $[La^-]_b$ concentration after the exhaustion test was statistically significantly higher on the day with rolling with a large effect size ($P < 0.05$; $d > 0.8$; Table 1).

Table 1. Measures of the Ramp cycle ergometer test to exhaustion.

					95% CI for Mean Difference		
	TT (SD)	**CT (SD)**	**Mean Difference (SE)**	**p**	**Lower**	**Upper**	**Cohen's d**
Time to exhaustion (s)	441 (106)	435 (93)	6.1 (9.9)	0.555	-17.2	29.5	0.219
VO_{2Peak} (ml/kg)	54.9 (9.2)	55.2 (9.1)	-0.34 (0.71)	0.650	-2.02	1.35	-0.168
RER	1.17 (0.03)	1.16 (0.05)	0.01 (0.01)	0.462	-0.02	0.05	0.275
At exhaustion $[La^-]_b$	16.6 (3.9)	14.8 (4.1)	1.8 (0.7)*	0.047	0.03	3.47	0.849

Note. * = p < 0.05; TT = Treatment test; CT = Control test; SD = Standard deviation; SE = Standard error of the difference; CI = Confidence interval; $[La^-]_b$ = Blood lactate concentration; RER = Respiratory exchange ratio.

3.2. The effect of massage on $[La^-]_b$ recovery between high intensity exercise.

During the 20 min post exercise to exhaustion, $[La^-]_b$ clearance was on average higher at each testing time-point when using 15 min of post exercise rolling compared to no rolling (Table 2). However, only the accumulated drop in $[La^-]_b$ at 10 min post exercise to exhaustion was statistically different with a large effect size ($d > 0.8$; $P = 0.004$). Further, the rate of $[La^-]_b$ clearance was on average 0.39 mmol·L^{-1}·min^{-1}, with no statistically significant differences between testing time-points, nor between testing conditions (Table 2).

Table 2. Measures of blood lactate ($[La^-]_b$) and $[La^-]_b$ clearance on a 5 min interval up to 20 min.

	TT (SD)	CT (SD)	Mean Difference (SE)	p	95% CI for Mean Difference: Lower	95% CI for Mean Difference: Upper	Cohen's d
$[La^-]_b$ at end of 1st warm up	2.4 (1.2)	2.0 (0.8)	0.33 (0.24)	0.217	-0.24	0.89	0.480
$[La^-]_b$ at exhaustion	16.6 (3.9)	14.8 (4.1)	1.75 (0.73)*	0.047	0.03	3.47	0.849
$[La^-]_b$ clearance after 5 min	3.3 (1.9)	2.6 (2.0)	0.76 (0.74)	0.338	-0.99	2.52	0.363
$[La^-]_b$ clearance after 10 min	5.3 (1.5)	4.2 (1.6)	1.10 (0.27)*	0.004	0.47	1.73	1.466
$[La^-]_b$ clearance after 15 min	7.1 (2.2)	5.9 (1.8)	1.16 (0.82)	0.197	-0.77	3.09	0.504
$[La^-]_b$ clearance after 20 min	8.6 (1.8)	7.8 (1.6)	0.79 (0.74)	0.320	-0.95	2.53	0.378
$[La^-]_b$ at end of 2nd warm up	4.0 (3.2)	3.2 (2.4)	0.89 (0.52)	0.128	-0.33	2.10	0.610

3.3. The effect of massage on the consecutive high intensity exercise.

None of the measured variables from the Wingate anaerobic cycle ergometer test had a statistically significant difference (Table 3). However, the average results indicated a tendency for a moderately higher (d = 0.7) peak power output on the day with rolling compared to the day without rolling (P = 0.084). Further, the results indicate a small effect on rate of fatigue (d < 0.49), and a trivial effect in 30 s average power (d < 0.2).

Table 3. Measures of Wingate anaerobic cycle ergometer test.

	TT (SD)	CT (SD)	Mean Difference (SE)	p	95% CI for Mean Difference: Lower	95% CI for Mean Difference: Upper	Cohen's d
PP (Watt)	735 (159)	718 (152)	16.6 (8.2)	0.084	-2.93	36.05	0.710
RPP (watt/kg)	11.4 (1.5)	11.2 (1.4)	0.24 (0.13)	0.109	-0.07	0.54	0.649
AP (Watt)	629 (144)	630 (140)	-1.5 (6.8)	0.832	-17.48	14.51	-0.078
RoF (%)	26.3 (6.8)	24.3 (7.9)	2.0 (1.5)	0.218	-1.49	5.47	0.478

Note. PP = Peak power; RPP = Relative peak power; AP = Average power; RoF = Rate of fatigue.

4. Discussion

The present study was designed to investigate the acute effect of quadriceps myofascial massage on performance and recovery using a novel designed mechanical self-induced multi-bar massage rolling machine on eight young elite speed skaters. The main findings of 10 min pre-warm-up rolling were; (i) a statistically significantly higher $[La^-]_b$ at the end of the exercise to exhaustion test (1.75 ± (SD) 2.06 $mmol \cdot L^{-1}$; $d > 0.8$; $P < 0.05$) and; (ii) no statistical significance combined with trivial and small effects on vO_{2peak} and time to exhaustion, respectively. Further, the main finding during recovery after the exercise to exhaustion test was; (iii) a statistically significant accumulation of $[La^-]_b$ clearance after 10 min of rolling with a large effect size. Furthermore, rolling 15 out of 30 min of recovery between the two high intensity tests gave; (iv) a non-significant trivial effect on average power, but (v) a tendency for a medium positive effect on peak power ($d = 0.7$, $P = 0.084$) in the consecutive 30 s Wingate test.

4.1. The rolling effect on test to exhaustion.

In this study, it was-hypothesized that quadriceps muscles rolling could potentially affect endurance performance through reducing locally limitations of aerobe power and/or anaerobe capacity. The aerobe performance indicator, vO_{2peak}, has been shown to be both centrally and locally limited when highly trained cross-country skiers ($vO_{2peak} > 65$ $ml \cdot kg^{-1} \cdot min^{-1}$) were tested in different exercise modes [43]. However, in the present study, quadriceps muscles rolling gave a trivial effect with no statistical significant difference on vO_{2peak}, which is in line with previous studies [23, 44].

On the other hand, $[La^-]_b$ was statistically significant higher after the test to exhaustion on the day with rolling (Table 1), which points out a larger buffering of $[La^-]b$ during the test to exhaustion, since $[La^-]_b$ after the 1st warmup did not vary notably between test days. (0.33 ± (SD) 0.68 $mmol \cdot L^{-1}$; Table 2) and the respiratory exchange ratio, which was observed in both testing days (Table 1). Theoretically, an increase of 1 $mmol \cdot l^{-1}$ of $[La^-]_b$ is equivalent to ~3 $mL \cdot kg^{-1}$ of oxygen consumed with an respiratory exchange ratio = 1.0 [45]. Thus, theoretically the average person in the present study could increase total energy expenditure equivalent to energy from approximately 335 ml of oxygen. Such an increase in anaerobic capacity would be expected to enhance performance in terms of time to exhaustion (at an effort equal to $_VO_{2peak}$, the 335ml of extra oxygen would last ~6 s). Interestingly, examining time to exhaustion indicated that participants continued on average 6.1 (9.9) s longer on the day with rolling compared to the day without rolling (Table 2). Nevertheless, the change was not statistically notable and the effect size of the massage condition was found to be small (*d* = 0.219; Table 1).

4.2. The rolling effect on recovery and consecutive test of anaerobic capacity

In this study, a 30 min recovery between the two performance tests was used as it simulates a sport specific situation [1]. Considering the intensity and duration of the speed skating races, studies from other sports indicate that 30 min of recovery might be close to enough between races [4, 47]. However, in the present study, the skaters still had elevated $[La^-]_b$ at the end of the second warmup compared to the first, indicating the importance of recovery strategy to performance.

The rate of $[La^-]_b$ clearance tended to be largest during the early phase of recovery and the results showed a statistically significant larger accumulated $[La^-]_b$ clearance (with a large effect size) after rolling for 10 min (Table 2). The different clearance of $[La^-]_b$ could be due to; (i) the effect of rolling on test to exhaustion performance (higher tolerance to high intensity exercise indicated by higher $[La^-]_b$ and longer working time) or; (ii) due to rolling during the recovery time provided. Nevertheless, maintaining rolling from 10^{th} to 15^{th} min during recovery, did not increase the rate of $[La^-]_b$ clearance. On the other hand, the average difference in $[La^-]_b$ clearance decreased between the 15^{th} and the 20^{th} min, when the massage was ended (Table 2).

There is no doubt that the test to exhaustion was highly intensive. So was the 30 s Wingate test, which was used as the second performance test. It estimates anaerobic capacity [40] and changes in Wingate performance test has been shown to predict changes in 1500 m speed skating performance [9]. A time gain of ~0.3 s on a 1500 m is a worthwhile change for a world-class skater (>10% more medals for a medal candidate), while the smallest worthwhile change is somewhat larger for junior skaters with larger variations [48]. Hofman et al. [9] reported the smallest worthwhile change in Wingate peak power and mean power to be 0.38 and 0.14 W/kg for females, and 0.29 and 0.12 W/kg for males, respectively. The results from the present study showed a tendency towards a medium positive effect on peak power in the Wingate test on the day of massage (Table 3). However, the peak power and mean power differences observed in the present study, were smaller than the smallest worthwhile changes reported by Hofman et al. [9].

4.3. Methodological considerations.

Contrary effects of massage and rolling has been reported in the literature [5, 21-23, 25-27, 30] using different number of participants, massage techniques and equipment's. The major challenges in this study was the number of participants (eight subjects), duration of the treatment (acute effect) and the interval (5 min) in which the $[La^-]_b$ was measured. The sample size in the present study was small for detecting effects of rolling giving a low statistical power. However, the statistical power was calculated at 80% for 8 participants and the Standard Deviation was found to be (SD) = 5.28 for $[La^-]_b$. None of the measures in this study exceeded an SD over 3.24 $mmol \cdot L^{-1}$. Further, it is challenging to find a large homogeneous sample size from individual elite sports. Furthermore, data from small samples could still be of interest for coaches and athletes and could be the basis for a future meta-analysis studies [49]. Since there were both male and female participants in this study, it was expected a larger SD for test to exhaustion results (vO_{2peak}) and Power, where males test results is better than females. In contrast, $[La^-]_b$ and respiratory exchange ratio were not affected by gender due to the fact that $[La^-]_b$ and respiratory exchange ratio is exercise intensity and duration dependent [10-12].

5. Conclusions

Despite the potential improvement observed in $[La^-]_b$ and Wingate peak-power results, acute rolling gave no marked performance improvements. Nevertheless, nor any indications for negative effects were observed. Hence, using the mechanical self-induced multi-bar massage roller do not seem to be harmful. The results of this study and past studies suggest the need for examining performance effects of self-induced massage on athletes long-term performance effects of self-induced massage.

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