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EFFECTS OF STANDING VS. SEATED POSTURE ON REPEATED WINGATE PERFORMANCE

JOHN R. MCLESTER, JAMES M. GREEN,[2] AND JEREMY L. CHOUINARD[1]

[1]Department of Physical Education and Recreation, Western Kentucky University, Bowling Green, Kentucky 42101; [2]Department of Kinesiology, The University of Alabama, Tuscaloosa, Alabama 35487.

ABSTRACT. McLester, J.R., J.M. Green, and J.L. Chouinard. Effects of standing versus seated posture on repeated Wingate performance. *J. Strength Cond. Res. 18(4):000–000. 2004.*—Standing during cycling may increase overall muscular activity. However, effects of standing vs. seated posture on performance measures during repeated bouts have not been extensively explored. The purpose of this study was to examine the effects of standing vs. seated posture on repeated Wingate performance. Healthy volunteers ($n = 35$) performed 3 consecutive Wingate anaerobic power tests (W_1, W_2, W_3) in a standing (STA) as well as seated (SIT) posture. Within-group comparisons were made for peak power, mean power, minimum power, and fatigue index. Results were considered significant at $p \leq 0.05$. No significant differences were found for peak power in W_1, W_2, or W_3. No significant difference was found for mean power in W_1 or W_2, but significant differences were found for mean power in W_3 (STA: 451.5 ± 105.3, SIT: 425.7 ± 110.0); minimum power in W_1 (STA: 433.6 ± 100.8, SIT: 381.5 ± 96.9), W_2 (STA: 348.1 ± 112.9, SIT: 308.0 ± 95.8), W_3 (STA: 292.0 ± 103.6, SIT: 265.3 ± 90.8); and fatigue index: W_1 (STA: 51.3 ± 10.7, SIT: 56.9 ± 9.3), W_2 (STA: 56.5 ± 12.6, SIT: 61.8 ± 12.2), W_3 (STA: 59.4 ± 13.1, SIT: 63.6 ± 12.4). Results suggest that a standing posture enhances performance during repeated Wingate cycling. The enhancement is most likely due to an attenuated loss in power, which in turn improves fatigue index.

KEY WORDS. anaerobic power, cycling, cycling position, exercise position, power output

INTRODUCTION

Cycling performance while standing has been of interest for some time among competitive cyclists because many courses have multiple hills and it is common for cyclists to stand up while climbing hills (13). This preference for standing while climbing hills has led to much investigation in biomechanical, electromyography (EMG), and metabolic differences between seated and standing cycling. However, investigations comparing standing and seated posture on anaerobic power output are limited.

Experienced cyclists demonstrate higher $\dot{V}O_2$ values as a result of standing (12, 14, 15). It has been speculated that cyclists' preference for standing in spite of higher energy requirement may be due to availability of power output (12). In other words, there must be some benefit to this position if cyclists are willing to expend more energy. It has also been found that there is a decreased sensation of effort observed in trained subjects during standing cycling (14). Decreased sensation of effort may speculatively relieve specifically fatigued muscles.

EMG activity during standing cycling is also higher (6, 15), possibly because of supporting the body weight (12). Also, there has been some investigation into the relative roles of mono- vs. biarticular muscles during jumping and cycling (16–18). Because of the speculation that monoarticular muscles tend to perform positive work whereas biarticular muscles tend to control direction of pedal force and transportation of force to adjacent joints (16–18), Li and Caldwell (6) used EMG to investigate the differences in activation of these types of muscles during standing vs. seated cycling. The investigators (6) found that standing cycling produced a greater change in EMG activity of the monoarticular gluteus maximus and vastus lateralis muscles when compared to the biarticular rectus femoris and biceps femoris muscles. This could translate into reduced fatigue of the biarticular muscles and selective fatigue of monoarticular muscles during standing cycling.

However, even though Li and Caldwell (6) found that gluteus maximus activity was higher during standing cycling, the hip extensor moment was seen to decrease in some subjects. Authors (6) attributed this to a more forward position of the hip joint in relation to the crank spindle, therefore reducing the moment arm of the vertical pedal reaction force relative to the hip joint axis. The investigators (6) therefore concluded that the increased gluteus maximus activity in the standing condition was associated with either increased hip joint stiffness or the need for greater stabilization of the pelvis. If hip extensor moments are not higher during standing cycling, there may not be a benefit to standing during anaerobic power activities. Also, if there is an increased need for stabilization of the pelvis in the standing condition (due to lack of support from the seat), there may be some increased levels of fatigue in pelvic stabilizers during cycling.

Regardless of the differences in metabolic demand, perception of effort, or EMG, cyclists must derive some benefit from standing during uphill cycling. If there is an increase in muscle activation during standing cycling, power output should be higher in the standing position. Reiser et al. (10) did indeed find power output to be higher in the standing position, but there was no effect on fatigue index. Because of the possibility that there may be multiple hills in a course and that the positive effects of standing may only appear later in the course, the effect of standing over repeated bouts needs to be investigated. Even though Wingate testing has been studied and written about extensively (1–3, 5, 7, 9–11), the authors have no knowledge of an investigation into the effects of standing while performing repeated bouts of anaerobic cycling. It is the belief of the authors that there is some positive effect of standing during cycling, which cannot be attributed to higher peak power output. The authors would also like to know if that effect becomes evident only after several instances of standing. Therefore, the purpose of this study was to investigate the possible benefits of standing

TABLE 1. Mean (± SD) power performance variables for standing and seated Wingate trials.

	Peak power	Mean power	Minimum power	Percent decrease
Standing				
W_1	930.3 ± 283.7	601.5 ± 141.8	433.6 ± 100.8*	51.3 ± 10.7*
W_2	815.6 ± 225.0	511.0 ± 127.9	348.1 ± 112.9*	56.5 ± 12.6*
W_3	733.1 ± 186.6	451.5 ± 105.3*	292.0 ± 103.6*	59.4 ± 13.1*
Seated				
W_1	911.5 ± 256.3	586.3 ± 144.3	381.5 ± 96.9	56.9 ± 9.3
W_2	850.1 ± 233.1	495.4 ± 121.1	308.0 ± 95.8	61.8 ± 12.2
W_3	764.8 ± 212.1	425.7 ± 110.0	265.3 ± 90.8	63.6 ± 12.4

* Significant difference ($p \leq 0.05$) between the standing and seated positions.

during cycling on power output and fatigue index during repeated Wingate bouts.

METHODS

Experimental Approach to the Problem

In counterbalanced order, the subjects participated in 2 laboratory sessions (1 session involved 3 seated Wingate trials and 1 session involved 3 standing Wingate trials). Each subject participated in a warm-up consisting of 4 minutes of seated cycling at 50 RPMs with 1 kg of resistance on a cycle ergometer designed for immediate-load resistance and toe clips to prevent foot slippage (Monark Ergomedic 824E, Sweden). Following warm-up, the proper resistance was added to the cycle as they prepared for the first test. The resistance for the lower-body Wingate testing was determined by computer software (SMI Power 5.2, Sports Medicine Industries, St. Cloud, MN), using 7.5% of body mass. Even though 7.5% of body mass may be too low for optimization of power in some adults (3), it was used for this particular study because of the intense physical challenge of repeated Wingate bouts. The Wingate testing began by instructing the subjects to begin pedaling (in the seated position) as fast as possible with no resistance. When maximum RPMs were reached, the weight basket was dropped and testing began. For the seated trials, subjects were required to remain seated throughout the entire test. The first Wingate trial (W_1) was followed by 2 identical Wingate tests (W_2 and W_3), as described above, with 4 minutes of recovery between each trial. The end result was 3 consecutive lower-body Wingate tests with 4 minutes of recovery between trials. The standing trials began with subjects in the seated position, but subjects were instructed to raise themselves off the seat (while keeping a bend in the knee and hands on the handlebars) when the basket was dropped. Subjects were told to remain standing throughout the trial. Subjects were verbally motivated to continue at the fastest rate possible for the complete 30-second test.

During the Wingate bouts, data for peak power, mean power, minimum power, and fatigue index were collected at 1-second intervals via an optical sensor (OptoSensor, Sports Medicine Industries) interfaced with computer software (SMI Power 5.2, Sports Medicine Industries). Data were collected and analyzed for all variables because of the possibility of standing having multiple effects.

Subjects

Thirty-five subjects (26 men and 9 women), primarily from Physical Education classes, volunteered to participate in the study. Each subject signed an informed consent and completed a medical history questionnaire prior to the study. The subjects were measured for height, mass, and body composition. Height was measured using a standard stadiometer, followed by mass on a standard balance scale (Detecto-Medic, Detecto Scales Inc., Brooklyn, NY). Body composition was measured with skinfold calipers (Lafayette Instrument Company, Lafayette, IN) using the 3-site skinfold method (4).

The men had a mean height of 180.4 ± 7.8 cm, with a mean mass of 86.8 ± 15.9 kg and a mean body fat of 13.3 + 6.8%. The women had a mean height of 166.2 ± 5.9 cm, with a mean mass of 56.1 ± 8.2 kg and a mean body fat of 19.1 ± 5.4 %. The study was approved by the local review board for the testing of human subjects.

Statistical Analyses

Because both men and women participated in the study and that there is difficulty standardizing a standing Wingate trial, a counterbalanced within-subjects design was implemented. In addition, because the subjects are essentially being compared to themselves, absolute values were used in data analysis.

Values were analyzed using SPSS for windows statistical program (v. 10.0). Repeated measures ANOVAs were used for within-group comparisons (standing vs. seated) for peak power, mean power, minimum power, and fatigue index (peak power − minimum power)/peak power · 100). When ANOVA indicated a significant difference, a Bonferroni post hoc procedure was used to detect specific differences between the variables in different trials. Results were considered significant at $p \leq 0.05$.

RESULTS

Table 1 displays the peak, mean, and minimum power data, as well as fatigue index in power for seated and standing trials.

Figure 1 depicts differences in peak power for the standing and seated trials. No significant differences ($p > 0.05$) between the standing and seated positions were found for peak power: W_1 (STA: 930.3 ± 283.7, SIT: 911.5 ± 256.3), W_2 (STA: 815.6 ± 225.0, SIT: 850.1 ± 233.1), W_3 (STA: 733.1 ± 186.6, SIT: 764.8 ± 212.1).

Figure 2 depicts differences in mean power for the standing and seated trials. No significant difference ($p > 0.05$) was found between the standing and seated positions for mean power W_1 (STA: 601.5 ± 141.8, SIT: 586.3 ± 144.3) or W_2 (STA: 511.0 ± 127.9, SIT: 495.4 ± 121.1), but a significant difference was found for mean power W_3 (STA: 451.5 ± 105.3, SIT: 425.7 ± 110.0; $p = 0.002$).

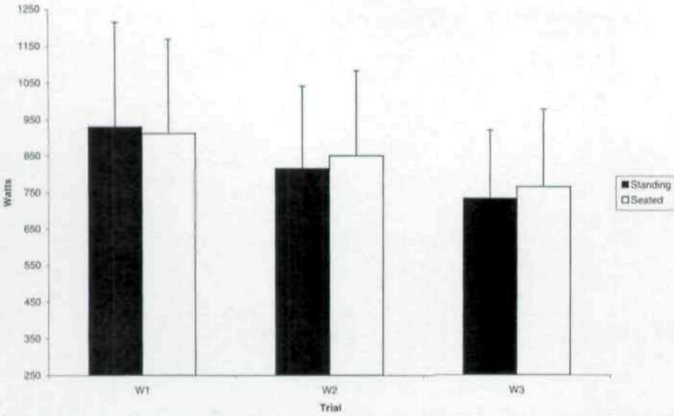

Figure 1. Changes in peak power (mean ± *SD*) for the standing and seated positions over the 3 trials. No significant differences ($p > 0.05$) between the standing and seated positions were found.

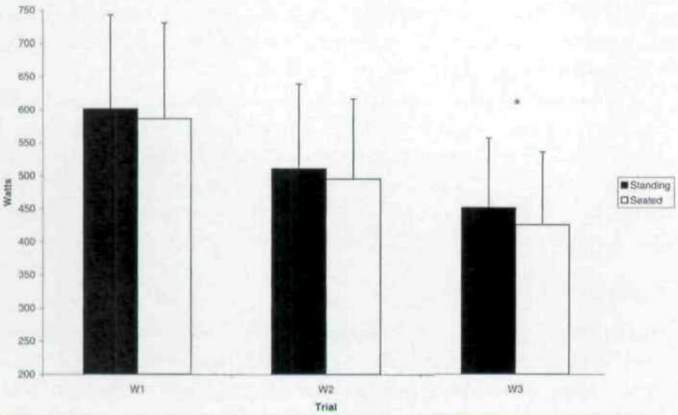

Figure 2. Changes in mean power (mean ± *SD*) for the standing and seated positions over the 3 trials. * Significant difference ($p \leq 0.05$) between the standing and seated positions.

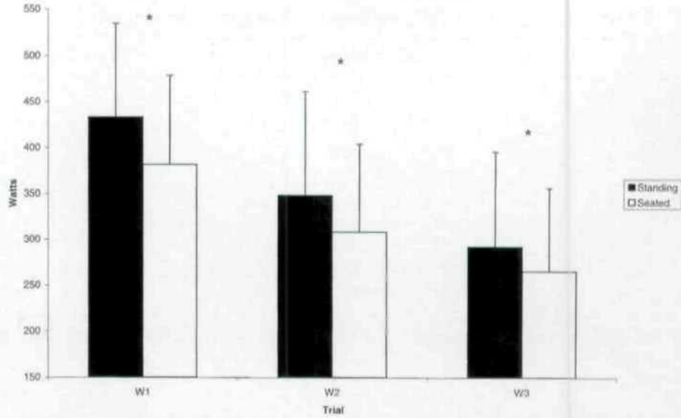

Figure 3. Changes in minimum power (mean ± *SD*) for the standing and seated positions over the 3 trials. * Significant difference ($p \leq 0.05$) between the standing and seated positions.

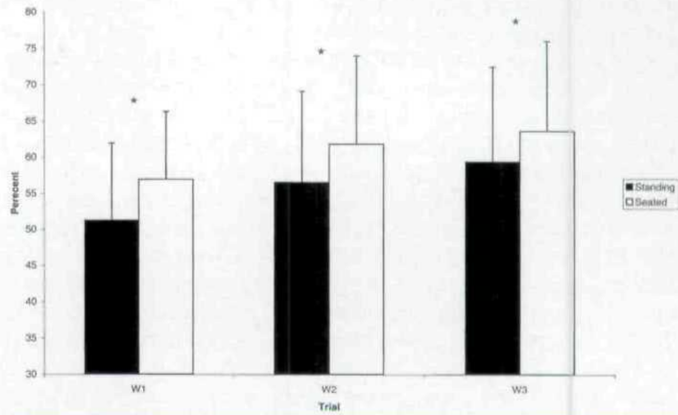

Figure 4. Changes in fatigue index (mean ± *SD*) for the standing and seated positions over the 3 trials. * Significant difference ($p \leq 0.05$) between the standing and seated positions.

Figure 3 depicts differences in minimum power for standing and seated trials. Significant differences were found between the standing and seated conditions in minimum power for all 3 trials: W_1 (STA: 433.6 ± 100.8, SIT: 381.5 ± 96.9; $p = 0.000$), W_2 (STA: 348.1 ± 112.9, SIT: 308.0 ± 95.8; $p = 0.000$), W_3 (STA: 292.0 ± 103.6, SIT: 265.3 ± 90.8; $p = 0.006$).

Figure 4 depicts differences in fatigue index for standing and seated trials. Significant differences were also found between the standing and seated conditions in fatigue index for all 3 trials: W_1 (STA: 51.3 ± 10.7, SIT: 56.9 ± 9.3; $p = 0.002$), W_2 (STA: 56.5 ± 12.6, SIT: 61.8 ± 12.2; $p = 0.001$), W_3 (STA: 59.4 ± 13.1, SIT: 63.6 ± 12.4; $p = 0.015$).

Discussion

The purpose of this study was to investigate power output variables between standing and seated postures during repeated bouts of Wingate cycling. The major finding of the study was an improvement in fatigue index during standing cycling, most likely due to higher minimum power output.

Contrary to previous findings (10), it can be seen in Figure 1 that no significant difference in peak power was found between the standing and seated positions for any of the 3 trials. However, this could have been due to slight differences in protocol (e.g., differences in resistance) or subject characteristics. Although muscle activation patterns through EMG were not evaluated in the current study, results correspond with EMG results of Li and Caldwell (6). These investigators (6) found that from the 6 muscles examined, only the gluteus maximus (increased 50%) and tibialis anterior (increased 40%) demonstrated significant differences in peak EMG. Assuming this occurred in the current study, increased activity of the gluteus maximus did not result in a greater peak power, probably due to a decreased hip extensor moment in the standing position (6).

In Figures 2 and 3, it can be seen that significant differences were found between the standing and seated conditions for mean power in trial 3 and for minimum power in all 3 trials. These results were also consistent with the EMG data of Li and Caldwell (6). The investigators (6) found increased mean and integrated EMG activity for both the gluteus maximus and rectus femoris. The higher integrated EMG of the gluteus maximus was found to not only be higher because of higher activity level, but also because of higher activity over a greater crank

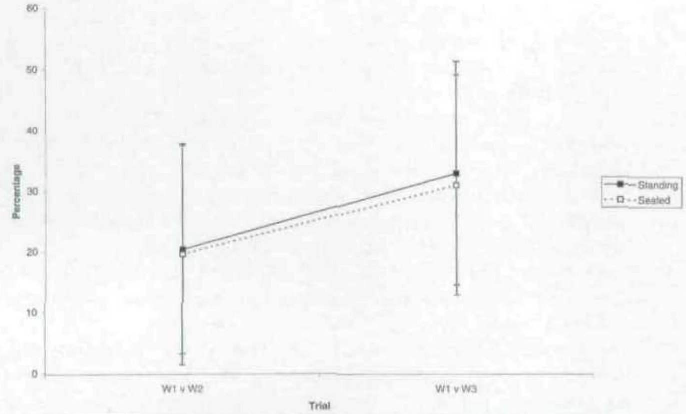

FIGURE 5. Minimum power delta values (mean ± *SD*) for the standing and seated positions. No significant differences ($p > 0.05$) between the standing and seated positions were found.

angle. Similarly, because no concomitant increase in peak EMG was found for the rectus femoris along with its higher mean and integrated EMG, the greater activity was attributed to its being active over a greater range of crank angles (6). Also, although differences in activity levels did not reach significance, Li and Caldwell (6) found that during standing the vastus lateralis muscle may have been activated earlier in the upward recovery phase and contracted longer in the downward phase. Again, although the current investigation did not utilize EMG, the possibility that these muscles are active over a greater range of the crank cycle could explain the significant increases in minimum power while in the standing position.

Also contrary to previous findings (10), it can be seen in Figure 4 that significant differences in fatigue index were found in all 3 trials. Because the fatigue index is a function of both peak and minimum power, and no significant differences were found for peak power, the lower fatigue index values in the standing condition must have been because of higher minimum power values.

Although it could be speculated that the differences in fatigue index indicate reduced fatigue over the course of the 3 standing trials, it should be kept in mind that minimum power and fatigue index were already significantly different between the 2 positions on the first trial. Therefore, as mentioned previously, the differences may simply be indicative of a greater minimum power due to greater muscle activity throughout the crank cycle. In other words, there may be an advantage in each individual trial because of greater available musculature, but not necessarily an advantage in fatigue index in successive bouts. In order to test this hypothesis, delta values for minimum power [(Minimum Power 1 − Minimum Power 2/Minimum Power 1·100 and (Minimum Power 1 − Minimum Power 3)/Minimum Power 1·100] were analyzed for the standing and seated positions. The aforementioned procedure was recommended by Michael (8) for calculating peak and mean power percent fatigue. This procedure permits repeated trials to be compared using the initial trial performance as a criterion standard. Bouts can be compared more objectively specifically when decrements in performance are consistent between successive bouts, yet different with respect to the initial criterion performance (trial 1). As can be seen in Figure 5, delta values were not significantly different between the standing and seated conditions. Therefore, there is apparently an advantage to standing during any given individual Wingate trial because of increased minimum power. However, according to these data, there is probably no additional advantage to standing when the bouts are repeated.

Data from the present study suggest that there is an advantage to standing during an individual Wingate cycling trial because of elevated minimum power, which in turn reduces fatigue index. However, because of a lack of significant difference in minimum power delta values between the 2 positions, there is no additional advantage from incorporating a standing position in repeated Wingate cycling trials. In addition, based on previous EMG data of Li and Caldwell (6) and because significantly higher minimum power values were not accompanied by higher peak power values, the advantage to standing during Wingate cycling may be because of greater muscular availability over a greater range of the crank cycle.

PRACTICAL APPLICATIONS

The major practical application of the finding from this study is in the area of power testing. Researchers should ensure that subjects are standardized during power testing with respect to position. Although this observation is obvious from a research methods perspective, sometimes subjects very slowly transfer from one position to the next. Also, the nature of the study may be better suited to one position or the other. If methods do require a standing posture, researchers should be aware of the affects of that posture on power test results.

A related issue is that of seat position during testing. The results of this study reiterate the importance of not only standardizing seat position within subject trials, but also how vital choosing the appropriate seat position is from the onset. It is obvious from these results that choosing a seat position that is either too high or too low may impact power test results. In other words, a seat that is too high may have similar implications as standing, even though a subject is "sitting" on the seat.

One other application that should be considered is the position of trained cyclists during power testing. In accordance with the principle of specificity, testing of cyclists in a standing position may be warranted in order to allow the greatest possible advantage.

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Address correspondence to John R. McLester, john.mclester@wku.edu.

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