*Journal of Physical Education and Sport* ® (JPES), Vol. 22 (issue 3), Art 86, pp. 690 – 695, March 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

**Original Article**

# Effect of body position during the Wingate Test

JAKUB KADLEC[1], DAVID MARKO[2], JOSEPH D VONDRASEK[3], PETR BAHENSKÝ[4]
[1,4] Department of Sports Studies, Faculty of Education, University of South Bohemia, CZECH REPUBLIC
[2]Sport Research Center, Faculty of Physical Education and Sport, Charles University, Prague, CZECH REPUBLIC
[3] Department of Health Sciences and Kinesiology, Georgia Southern University Armstrong Campus, Savannah, GA, USA

Published online: March 31, 2022
(Accepted for publication March 15, 2022)
**DOI:10.7752/jpes.2022.03086**

***Abstract***
The 30-second Wingate anaerobic test (30-WAT) is a well-established assessment of peak anaerobic power output (absolute and relative) and represents the physiological demands of a short sprints that competitive cyclists perform while they are starting a race or attacking at a finish. During these short sprints it is common for athletes to raise out of the saddle and assume a standing position. However, the 30-WAT is usually completed in a seated position which is dissimilar to the standing sprints observed in cyclists. The change in anaerobic power output during different riding positions is important for athletes and coaches to consider when testing maximum power output. **Purpose:** The purpose of this investigation was to compare anaerobic power output in a group of competitive cyclists while they completed multiple 30-WATs in different riding positions. **Methods:** Thirteen competitive male mountain bikers (20.5 ± 2.5 years) performed three 30-WATs on non-consecutive days over the course of one week. Each participant completed 1 only sitting (SIT), 1 only standing (STD), and 1 combination (COMB) test in which they started in a seated position and transitioned to a standing position at the halfway mark (~15s). The testing order was randomized for all participants. Each 30-WAT was completed on a LODE Excalibur Sport (Lode B.V., Groningen, The Netherlands) ergometer. Power was monitored using a commercially available software/hardware package (Lode B.V., Groningen, The Netherlands). Data were analyzed using a one-way repeated measures analysis of variance ($\alpha$=0.05). **Results:** Absolute power output during SIT (724±82 W) was significantly lower ($p < 0.01$) than outputs during STD (744±81 W) and COMB (746±81 W) protocols. Furthermore, relative power was significantly lower in SIT (9.5±0.7 $W \cdot kg^{-1}$) compared to STD (9.8±0.7 $W \cdot kg^{-1}$) and COMB (9.8±0.6 $W \cdot kg^{-1}$) protocol. Amongst all measured variables, no statistical differences were detected between the STD and COMB protocols. **Conclusion:** Greater power outputs were achieved when cyclists utilized a standing position or changed to a standing position halfway through the 30-second test. It may be more appropriate to assess a competitive cyclist's performance during a 30-WAT test in a standing or partially standing position to accurately quantify peak anaerobic output.
***Key Words*: anaerobic test, cycling position, performance, mountain bikers**

## Introduction

In cycling competitions (road, cyclocross, mountain, etc.), aerobic and anaerobic capacity both influence overall performance. Short burst of anaerobic output is imperative for optimal outcomes in specific sections of each race. Athletes use short bursts of anaerobic output to start, attack, overcome steep climbs, and sprint to bonuses. During these sprints, it is common for a cyclist to raise out of the saddle from the seated position and transition to a standing position while continually pedaling. There is great interest in the effectiveness of this riding position given that it is commonly seen in cycling events and previous research suggests that the standing position may be the most effective position for maximal effort (anaerobic) short duration sprints (Rohsler et al., 2020).

Caldwell et al. (1998) characterized cycling movement from a biomechanical point of view and described alterations in kinetic patterns of pedal force when riding at flat (incline 0%) and pitched (incline 8%) grades. Results showed that the elite cyclists achieved higher torque and peak power values when they rode in the standing position during the simulated incline. These findings were attributed to the addition of non-muscular (gravitational and inertial) contributions to the driving force of each pedal stroke. These kinetic changes between the postures (seated and standing) are associated with modified pedal orientation (toe down) throughout the crank cycle. According to Li et al. (2004) a change in body position had a greater effect on neuromuscular coordination than the incline. When in a standing position there is an increased torque in the ankle and knee joint while the torque in the hip joint decreases. Li et al. (1998) used surface electromyography (EMG) in the standing position and found there to be greater activation of the rectus femoris, gluteus maximus, and tibialis anterior throughout the whole pedal stroke cycle; there were not observed changes in activity for the gastrocnemius and


Corresponding Author: DAVID MARKO, E-mail: dmarko@jcu.cz

biceps femoris between the standing and sitting positions. Bouillod et al. (2018) performed a biomechanical and physiological analysis of elite cyclists pedaling in the standing and sitting positions and did not note any speed changes when transitioning between sitting and standing position. However, they noted an increase of mechanical expenses and tangential force on the pedal (+19% and +22%). Furthermore, cadence was reduced (-8%) when utilizing the standing position. Bertucci et al. (2008) sought to assess the influence of cycling experience on riding position and observed no difference in performance when comparing sitting and standing in a group of elite cyclists. Moreover, there was not a difference between positions for recreational cyclists, suggesting there is not a requirement of experience. Ryschon et al. (1991) compared the metabolic cost of the sitting and standing positions via oxygen uptake and showed that when in a standing position there is a greater oxygen uptake and therefore higher energy output. Many sports outside of cycling also require repeated maximal efforts anaerobic sprints which necessitates the ability to quantify peak anaerobic output (Baron, 2001; Dorel et al., 2005; Delextrat & Cohen, 2008; Bringhurst, Wagner, & Schwartz, 2020). The 30-second Wingate anaerobic test (30-WAT) is a gold standard anaerobic assessment. The Wingate test is regularly used to evaluate high intensity exercise performance (Grgic, 2020; Wingate test rely on the capabilities of ATP/PC energy system which contributes to maximum anaerobic power (Krishnan, Sharma, Bhatt, Dixit, & Pradeep, 2017). During the test there are key outcomes that can be monitored and compared across time or between body positions. Key outcome measures are: peak power (PP), average power (AP), and the percentage of power decline from peak to trough (fatigue index = FI) (Vandewalle, 1987). Outcomes are also expressed in relative values of relative peak power (RPP) and relative average power (RAP); average cadence and peak heart rate (PHR) are also of interest. The Wingate test is specific to cycling motor patterns, but it is also used by athletes in other sports to assess selected parameters of anaerobic performance. (Bahenský, Bunc, Tlustý, & Grosicki, 2020; Bahenský, Marko, Bunc, & Tlustý, 2020; Jaafar et al., 2014; Krishnan, Sharma, Bhatt, Dixit, & Pradeep, 2017). The 30-WAT is an ideal test for the comparison of anaerobic power output across different riding positions.

The purpose of this investigation was to compare anaerobic power output characteristics (PP, AP, FI, RPP, RAP) in a group of competitive cyclists while they completed three distinct 30-WATs in three different riding protocols. The three iterations of the test were a sitting only test (SIT), a standing only test (STD), and a combined test (COMB) in which participants started in the seated position and transitioned to standing halfway (15s) through the test. We hypothesized that of the three protocols, the STD protocol would generate the most power while the COMB would produce the second most power, and the SIT protocol would produce the least. We also hypothesized that the STD ride would lead to a lower fatigue index than the SIT ride.

## Materials and Methods

*Participants*

All 13 participants (Table 1) were competitive mountain bikers at a national level. Participants completed the 3 30-WATs over the course of one week and each test was at least 48 hours apart. With three variations of the same test being completed, participants were randomized (randomizer.org) into 6 possible orders of 30-WAT completion (Table II). Before each test, participants were asked to abstain from alcohol for 48 hours and caffeine for 12 hours. Each participant was instructed to continue training and train at a low to moderate intensity for less than 2 hours the day before each 30-WAT. The risk of performing high-intensity exercise and changing riding position was made clear to each subject. All participants completed a written informed consent. There was no compensation for any of the cyclists and all protocols and procedures conformed to the Declaration of Helsinki statements and were approved by The Ethical Committees of Faculty of Education, University of South Bohemia study on October 19, 2018 (002/2018).

**Table I. Characteristic of participants**

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Age (years) | 20.5 | 2.5 | 17 | 25 |
| Body Mass (kg) | 76.1 | 6.4 | 64,1 | 88,5 |
| Height (cm) | 183.2 | 4.2 | 175 | 191 |
| Fat Percentage (%) | 11.5 | 3.5 | 4,2 | 17 |
| Weekly training (hrs) | 11.1 | 1.7 | 8 | 15 |

**Table II. Group Randomization**

| Order | Wingate 1 | Wingate 2 | Wingate 3 | Participants |
|---|---|---|---|---|
| 1. | SIT | STD | COMB | n = 2 |
| 2. | SIT | COMB | STD | n = 3 |
| 3. | STD | SIT | COMB | n = 2 |
| 4. | STD | COMB | SIT | n = 2 |
| 5. | COMB | SIT | STD | n = 2 |
| 6. | COMB | STD | SIT | n = 2 |

*Test protocol*

Upon arrival to the lab, body composition and weight were assessed using a digital scale (Tanita BC 418 MA, Tanita Europe BV, Amsterdam, The Netherlands). Conditions in the lab were similar across all 3 visits (22–24 °C).

All 30-WATs were completed on a LODE Excalibur Sport (Lode B.V., Groningen, The Netherlands) ergometer and individualized seat heights were determined. All tests were preceded by a 5-minute standardized warm-up (Figure I) which included 2 short sprints and concluded with a ramp-up that led immediately into the 30-WAT; participants were guided through the warm-up by a research assistant who provided verbal timing cues. Output data were measured and analyzed with Lode Ergometry Manager 10 (Lode B.V., Groningen, The Netherlands) software. Heart rate during each test was monitored with a Polar chest strap (model T34, Polar, Finland). All participants completed the 30-WAT tests with cycling shoes (SPD system) and verbal encouragement was given during all test.

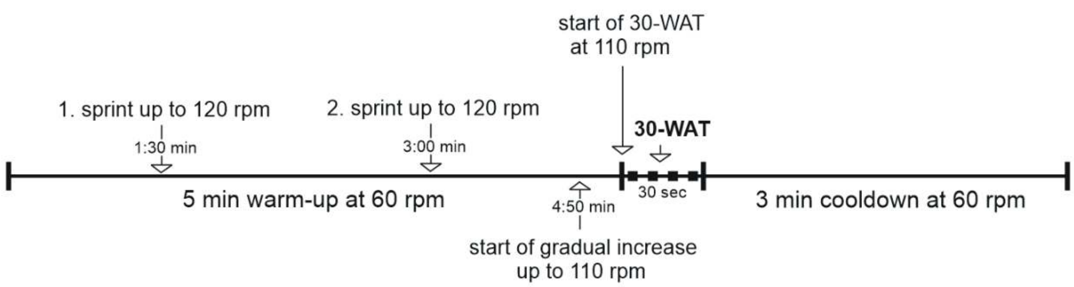


**Figure I**. 30-WAT protocol. The monitored variables of the 30-WAT were: peak power (PP), average power (AP), fatigue index (FI), relative peak power (RPP), relative average power (RAP), peak heart rate (PHR), and average cadence.

*Statistical analysis*

Data were analyzed using statistical software Rstudio (version 1.0.153; *RStudio*, Inc., Boston, MA). Normality was assessed with Shapiro-Wilks tests. One-way repeated measures analysis of variance, followed by Holm post hoc tests, were used to compare the three tests with an *a priori* alpha level <0.05. For effect size statistics, Cohen's *d* was used to determine practical significance. The scale of magnitude was as follows: small effect 0.20–0.5; moderate effect 0.5–0.8, large effect >0.8 (Cohen, 1988).

**Results**

Table III. presents main outcomes. Significant differences were observed in PP (*p=0.073, d=0.45*), RPP (*p=0.063, d=0.58*), AP (*p=0.001, d=0.25*), and RAP (*p=0.003, d=0.*41) between SIT and STD protocols. Significant differences were also observed for AP (*p<0.001, d=0.219*) and RAP (*p<0.001, d=0.397*) when comparing SIT and COMB protocols. No significant differences in FI or PHR were found. There was a moderate effect *(d=0.54) for FI between SIT and COMB and no differences between STD or COMB were detected.*

**Table IIII. Power output outcomes for 3 different 30-WAT protocols**

| | SIT | | STD | | COMB | |
|---|---|---|---|---|---|---|
| | Mean | ±SD | Mean | ±SD | Mean | ±SD |
| Peak Power (W) | 1127 | 156 | 1200 | 170 | 1137 | 154 |
| Average Power (W) | 724$^{***\ III}$ | 82 | 744 | 81 | 746 | 81 |
| Relative Peak Power (W·kg$^{-1}$) | 14.8 | 1.6 | 15.8 | 1.8 | 14.9 | 1.3 |
| Relative Average Power (W·kg$^{-1}$) | 9.5$^{***\ II}$ | 0.7 | 9.8 | 0.7 | 9.8 | 0.6 |
| Fatigue Index | 47 | 6 | 49 | 11 | 50 | 7 |
| Average Cadence (rpm) | 135$^{*}$ | 10 | 137 | 8 | 136 | 8 |
| Peak Heart Rate (bpm) | 179 | 13 | 180 | 8 | 183 | 12 |

*Note: Values of significant differences: vs. STD (p≤0.05)* $^{*}$, *(p≤0.01)* $^{**}$, *(p≤0.001)* $^{***}$, *vs. COMB (p≤0.05)* $^{I}$, *(p≤0.01)* $^{II}$, *(p≤0.001)* $^{III}$.

Figure II. presents the course of relative power throughout the 3 30-WAT protocols. Data shown in Figure II is the average of all 13 participants results. Each time point signifies the passing of 0.2 seconds.

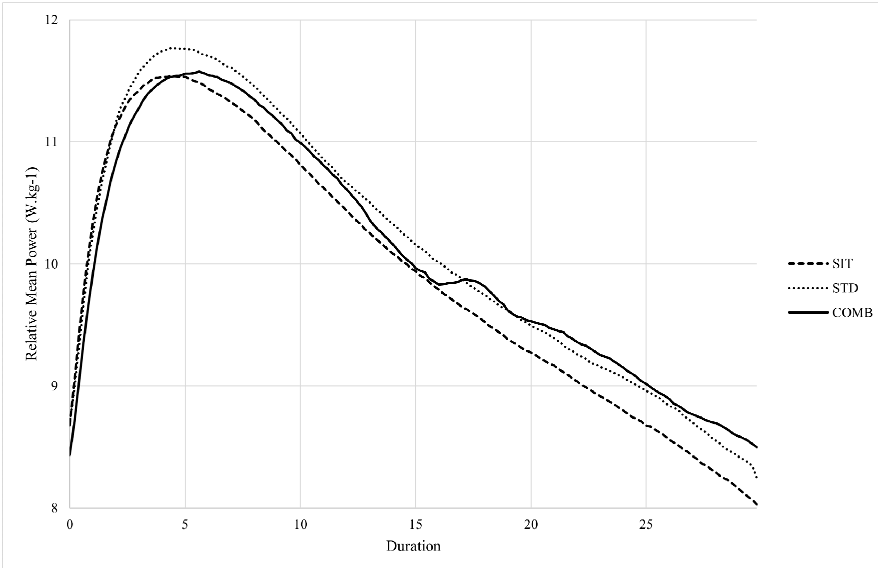


**Figure I. Mean relative power (W•kg$^{-1}$) for all 13 participants sampled every 0.2 seconds**

**Discussion**

The purpose of this investigation was to compare anaerobic power output characteristics (PP, AP, FI, RPP, RAP) in a group of competitive cyclists while they completed three distinct 30-WATs in 3 different position protocols. The key findings of this study were that cyclists generated higher power output values during the STD and COMB protocol compared to the SIT protocol and that for all measured variables there were no differences detected between the STD and COMB protocol. These data confirmed that not only the choice of the appropriate ergometer (Marko, Bahenský, Snarr, & Malátová, 2021), but also the cycling position influences anaerobic power outcomes.

These findings support previous literature which found differences in muscle activation and torque when comparing cycling positions. Previous work found there to be altered muscle activation patterns in the standing position (Li & Caldwell, 1998; Duc et al., 2008; Turpin et al., 2017). For example, Li & Caldwell (1998) showed the EMG output of the rectus femoris, gluteus maximus and tibialis anterior in the standing position was greater compared to seated. They talked about the extended neuromuscular activation of the rectus femoris and vastus lateralis throughout the pedal stroke. Likewise, Duc et al. (2008) noted higher intensity and duration of gluteus maximum, vastus lateralis, rectus femoris, biceps femoris and biceps brachii activation in the standing position while the semimembranosus activation was slightly decreased. These findings help explain some of the difference in power output in the STD and COMB position.

Merkes et al. (2020) noted the differences in maximum torque values between positions. Their cohort of participants reached peak torque earlier in the seated position than in the standing and the forward standing positions. They attributed this discrepancy in onset of peak torque to the greater involvement of the hip and knee extensors and flexors. Similarly, we found there to be an earlier achievement of peak power output in the SIT protocol; peak power was achieved slowest during the COMB protocol (Figure II). Interestingly, we found that the COMB protocol power curve was similar to the curve of the SIT protocol to start, but there was a change in output when the riders transitioned from sitting to standing. Immediately after the transition of the COMB protocol there is a distinct increase in power output values. These findings highlight differences in position and further highlight the impact that utilizing the standing position can have on anaerobic power output during cycling.

Previous work on the differences among standing and sitting during 30-WATs have had mixed results. Costa et al. (2021) noted no significant differences between positions when studying non-specialized participants from the general population. In a group of competitive (national and international) road cyclists, Rohsler et al. (2020) found there to be lower performance values in the Wingate tests during sitting versus standing: PP (1082 W vs. 1155 W, $p=0.019$), RPP (15 W·kg$^{-1}$ vs. 15.9 W·kg$^{-1}$, $p=0.033$), AP (818 W vs. 875 W, $p<0.001$), RAP (11.3 W·kg$^{-1}$ vs. 12.1 W·kg$^{-1}$, $p=0.001$). Wilson et al. (2009) conducted a similar experiment on professional speed skaters and found there to be no significant differences between positions when comparing power values, maximum heart rate, blood lactate, and muscle oxygenation. McLester et al. (2004) presented the results of 30-WATs in a group of students of physical education and found non-significant differences when comparing maximum power output values, but significant differences were found when comparing mean power values between sitting and standing. It is of note that fatigue index values were significantly lower in the standing position ($p\leq0.05$) in the third round of repeated 30-WATS. Reiser et al. (2002), conducted an experiment on a group of college competitive cyclists and reported significant differences (*p≤0.01*) between standing and sitting positions (1s peak 19.4 W·kg$^{-1}$ vs. 17.9 W·kg$^{-1}$, 5s peak 16.8 W·kg$^{-1}$ vs. 15.7 W·kg$^{-1}$, RAP 11.0 W·kg$^{-1}$ vs. 10.4 W·kg$^{-1}$, 5s minimal power 8.3 W·kg$^{-1}$, 7.5 W·kg$^{-1}$). In a non-Wingate study, Merkes et al. (2020) used a protocol in which a professional cyclist completed a 14s sprint, 10 minutes of high-intensity riding, and a final 14s sprint to simulate the conclusion of a cycling race. They assessed the difference between the three positions: sitting, standing, and forward standing (sprint position) and significant differences between sitting and standing positions were found when comparing PP (*p=0.001*) and AP (*p=0.009*) (Merkes, Menaspà, & Abbiss, 2020). Similarly, Bertucci et al. (2008) noted that recreational cyclists and elite cyclocross riders produced higher mean power output in 8s sprint in standing positions compared to sitting positions (recreational cyclists 966 W vs 867 W, elite cyclocross riders 1011 W vs. 892 W). Our current findings are in line with these prior outcomes which suggest previous cycling training may be a requirement of increased performance while utilizing the standing position. While there was not an improvement for the high-level speed skaters, well trained athletes, the group was still not comprised of cyclists. Wilson et al. (2009) noted that the differences between positions can be determined by factors of training level, pedaling technique, and sports specialization. It appears that there may not be an advantage to the standing position in a group of non-trained participants.

The results of pedal stroke cadence differ in several studies. Some authors found no significant differences between the positions (Bertucci et al. 2008; Merkes et al., 2020). Contrarywise, Reiser et al. (2002) observed significantly higher (127 rpm vs. 121 rpm; 5%) average cadence values while riding in the standing position. Rohsler et al. (2020) also found significantly higher cadence in the standing position (109.8 rpm vs. 117.5 rpm, *p<0.000*). We observed similar cadence outcomes among the 3 positions which adds to the mixed past findings.

A strength of this investigation was the comparison of the 3 riding positions on different days which allowed for true maximum effort during each 30-WAT while the relatively small sample of cyclists is a limitation of this investigation. Future investigations can potentially measure outcomes in larger data sets and also continue to compare and investigate differences among un-trained and trained populations to better understand the role that experience plays in anaerobic power outcomes across different cycling positions.

**Conclusions**

Competitive mountain bikers achieved significantly higher average and relative power during the 30-second Wingate anaerobic test in the standing only protocol and combination protocol compared to the sitting only protocol. These findings are in line with previous work which found there to be higher power output in the standing position among trained cyclists. These findings suggest that the most appropriate method for accurately testing a trained cyclist's peak anaerobic power output is a 30-WAT completed in a standing only or combined position protocol.

**Funding**

This research was supported by the grant SVV No. 260599. The authors declare no conflict of interest, financial or otherwise.

**References:**

Bar-Or, O. (1987). The Wingate anaerobic test an update on methodology, reliability and validity. *Sports medicine*, *4*(6), 381–394.

Bahenský, P., Bunc, V., Tlustý, P., & Grosicki, G. J. (2020). Effect of an Eleven-Day Altitude Training Program on Aerobic and Anaerobic Performance in Adolescent Runners. *Medicina, 56*(4), 184.

Bahenský, P., Marko, D., Bunc, V., & Tlustý, P. (2020). Power, Muscle and Take-off Asymmetry in Young Soccer Players. *International Journal of Environmental Research and Public Health*, *17*(17), 6040.

Baron, R. (2001). Aerobic and anaerobic power characteristics of off-road cyclists. *Medicine & Science in Sports & Exercise*, *33*(8), 1387–1393.

Bertucci, W., Taiar, R., Toshev, Y., & Letellier, T. (2008). Comparison of biomechanical criteria in cycling maximal effort test. *International Journal of Sports Science and Engineering*, *2*(1), 36–46.

Bouillod, A., & Grappe, F. (2018). Physiological and biomechanical responses between seated and standing positions during distance-based uphill time trials in elite cyclists. *Journal of sports sciences*, *36*(10), 1173–1178.

Bringhurst, R. F., Wagner, D. R., & Schwartz, S. (2020). Wingate anaerobic test reliability on the Velotron with ice hockey players. *Journal of Strength & Conditioning Research*, *34*(6), 1716–1722.

Caldwell, G. E., Li, L., McCole, S. D., & Hagberg, J. M. (1998). Pedal and crank kinetics in uphill cycling. *Journal of Applied Biomechanics*, *14*(3), 245–259.

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences. Routledge Academic: New York, NY, USA.

Delextrat, A., & Cohen, D. (2008). Physiological testing of basketball players: toward a standard evaluation of anaerobic fitness. *Journal of Strength & Conditioning Research*, *22*(4), 1066–1072.

Dorel, S., Hautier, C. A., Rambaud, O., Rouffet, D., Van Praagh, E., Lacour, J. R., & Bourdin, M. (2005). Torque and power-velocity relationships in cycling: relevance to track sprint performance in world-class cyclists. *International journal of sports medicine*, *26*(9), 739–746.

Duc, S., Bertucci, W., Pernin, J. N., & Grappe, F. (2008). Muscular activity during uphill cycling: effect of slope, posture, hand grip position, and constrained bicycle lateral sways. *Journal of Electromyography and Kinesiology*, *18*(1), 116–127.

Grgic, J. (2020). Effects of sodium bicarbonate ingestion on measures of Wingate test performance: a meta-analysis. *Journal of the American College of Nutrition*, 1–10.

Jaafar, H., Rouis, M., Coudrat, L., Attiogbé, E., Vandewalle, H., & Driss, T. (2014). Effects of load on Wingate test performances and reliability. *Journal of Strength & Conditioning Research*, *28*(12), 3462–3468.

Krishnan, A., Sharma, D., Bhatt, M., Dixit, A., & Pradeep, P. (2017). Comparison between standing broad jump test and wingate test for assessing lower limb anaerobic power in elite sportsmen. Medical Journal Armed Forces India, *73*(2), 140–145.

Li, L. (2004). Neuromuscular control and coordination during cycling. *Research quarterly for exercise and sport*, *75*(1), 16–22.

Li, L., & Caldwell, G. E. (1998). Muscle coordination in cycling: effect of surface incline and posture. *Journal of Applied Physiology*, *85*(3), 927–934.

Marko, D., Bahenský, P., Snarr, R. L., & Malátová, R. (2021). V̇O2peak Comparison of a Treadmill Vs. Cycling Protocol in Elite Teenage Competitive Runners, Cyclists, and Swimmers. *Journal of Strength and Conditioning Research*, Published Ahead-of-Print. DOI: 10.1519/JSC.0000000000004005

McLester, J. R., Green, J. M., & Chouinard, J. L. (2004). Effects of standing vs. seated posture on repeated Wingate performance. *Journal of Strength and Conditioning Research*, 18, 816–820.

Merkes, P. F., Menaspà, P., & Abbiss, C. R. (2020). Power output, cadence, and torque are similar between the forward standing and traditional sprint cycling positions. *Scandinavian journal of medicine & science in sports*, *30*(1), 64–73.

Rana, S. R. (2006). Effect of the Wingate test on mechanomyography and electromyography. *Journal of strength and conditioning research*, *20*(2), 292.

Ryan, M., & Gregor, R. (1992). EMG profiles of lower extremity muscles during cycling at constant workload and cadence. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology*, *2*(2), 69–80.

Reiser, R. F., Maines, J. M., Eisenmann, J. C., & Wilkinson, J. G. (2002). Standing and seated Wingate protocols in human cycling. A comparison of standard parameters. *European Journal of Applied Physiology*, *88*(1), 152–157.

Rohsler, R., Campos, F. D. S., Varoni, P. R., Baumann, L., Demarchi, M., Teixeira, A. S., ... Flores, L. J. F. (2020). Performance comparison in the Wingate test between standing and seated positions in competitive cyclists. *Motriz: Revista de Educação Física*, 26.

Ryschon, T. W., & Stray-Gundersen, J. (1991). The effect of body position on the energy cost of cycling. *Medicine and science in sports and exercise*, *23*(8), 949–953.

Turpin, N. A., Costes, A., Moretto, P., & Watier, B. (2017). Can muscle coordination explain the advantage of using the standing position during intense cycling? *Journal of Science and Medicine in Sport*, *20*(6), 611-616.

Vandewalle, H., Péerès, G., & Monod, H. (1987). Standard anaerobic exercise tests. *Sports medicine*, *4*(4), 268–289.

Wilson, R. W., Snyder, A. C., & Dorman, J. C. (2009). Analysis of seated and standing triple Wingate tests. *Journal of Strength & Conditioning Research*, *23*(3), 868–873.