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A new field test for the assessment of upper-body anaerobic power and capacity: from health to sport performance

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ABSTRACT

This study aimed to develop and determine the concurrent validity of the maximum interval push-up (MIPU) field test to assess upper-body anaerobic power and capacity. For this purpose, 72 physically active adult men performed either one upper-body Wingate Anaerobic test (WAnT; 30 s all-out) or one MIPU test (6 × 6-s all-out: 10-s recovery). The order of the tests was counterbalanced, with a 30-minute rest interval between them. Pearson's or Spearman's correlation coefficients were calculated to determine the relationships between variables. In the comparisons of the absolute values (W) obtained in the WAnT with the results of the MIPU test (rep*kg), a very large correlation was observed for peak power (r=0.75, p<0.001), a large correlation for mean power (r=0.62, p<0.001), and a moderate correlation for minimum power (r=0.27, p=0.021). When comparing the relative values (W/kg) obtained in the WAnT test with those of the MIPU test (rep*kg), large correlations were observed for peak power (r=0.57, p<0.001) and mean power (r=0.50, p<0.001). Thus, MIPU appears to be an easy and practical field test for assessing peak and mean upper-body power in adult men, with potential for use in the sports and health sectors.

KEYWORDS

Athletic Performance; Health; Sports Science

1. INTRODUCTION

Anaerobic capacity and power are fundamental for many sports because the decisive moments in competition depend on high-intensity actions, which cannot be supplied solely by oxidative metabolism (Buchheit & Laursen, 2013). Anaerobic power is considered the highest power produced from anaerobic pathways, which reflects the energy production power of anaerobic metabolism, especially through the ATP–CP pathway; its importance can be observed in sports of very short duration and high-intensity, which require energy almost exclusively from anaerobic metabolism (e.g., 100-m run, shot put, Olympic weightlifting). Anaerobic capacity is the average power produced from anaerobic pathways, which reflects the energy production capacity of the anaerobic system, especially through the contribution of the ATP-CP and glycolytic pathways (Beneke et al., 2002); its importance can be observed in those sports that heavily rely on anaerobic metabolism (e.g., 200-m run, 400-m run), or even in intermittent sports, which require anaerobic metabolism to perform determinant activities, such as explosive actions for attacks, counterattacks, and defenses (e.g., combat sports, handball, volleyball, basketball, soccer, rugby) (Andreato et al., 2022; Alkhawaldeh, 2022; Branco et al., 2018; Buchheit & Laursen, 2013; Gacesa et al., 2009; West et al., 2020). In addition, anaerobic capacity could be related to health since there is an association between upper-body exercise capacity and future cardiovascular events (Yang et al., 2019).

For the evaluation of anaerobic power and capacity, the most popular test used is the Wingate Anaerobic Test (WAnT), which was proposed by Bar-Or and colleagues in 1977 and includes a protocol for the assessment of 30 s of all-out effort on a cycle ergometer (Bar-Or et al., 1977; Bar-Or, 1978). Using this assessment model, it is possible to obtain several indicators of anaerobic metabolism, such as the peak and mean power (Beneke et al., 2002). The WAnT was initially proposed for lower-body evaluations but was later adapted for upper-body evaluations (Sharp et al., 1986). Despite its validity and effectiveness, the WAnT has significant limitations, including the need for expensive laboratory equipment and its restricted applicability, which limits its use for many individuals, particularly nonprofessional athletes and coaches (Prieto-González et al., 2022). These limitations highlight the need for accessible alternatives to assess anaerobic power and capacity.

While widely used and validated methods exist for evaluating lower-body anaerobic capacity, the assessment of upper-body anaerobic power and capacity remains underdeveloped. For the lower-body, the running-based anaerobic sprint test (RAST) was proposed by Draper and Whyte in 1997 (Draper & Whyte, 1997). The RAST is a simple test (6 sprints of 35-m runs interposed by 10-second intervals of passive recovery between bouts), which is easy to apply, has been validated, and presents greater ecological validity for sports involving running sprints (e.g., basketball, futsal, football, soccer) (Andrade et al., 2016; Flores Junior et al., 2017; Godwin et al., 2017; Pojskić et al., 2015). In addition to the RAST, some findings have demonstrated that 30 s of vertical jumps have strong correlations with lower-body WAnT, indicating that the former may adequately assess the lower-body anaerobic performance of young karate athletes (Čular et al., 2018) and elite cyclists (Muriel Otegui et al., 2012). However, for the upper-body, there is still a lack of accessible field tests for assessing both anaerobic power and capacity. This gap in the literature is crucial, as many sports require upper-body anaerobic performance, and there is a need for practical, valid field tests for such assessments.

Thus, the present study aims to develop and determine the concurrent validity of a field test for assessing upper-body anaerobic power and capacity in adult men. The working hypothesis of the study is that there is an association between WAnT and push-ups performed in a set amount of time.

2. METHODS

2.1. Study Design and Participants

First, volunteers were recruited through personal invitations extended to physical education university students and through the dissemination of research on social media (Facebook and Instagram). They were selected according to the criteria presented in the participants' topic. After being briefed on the procedures and purpose of the study, the volunteers signed a written and informed consent form prior to participation. The study was performed following the 466/2012 resolution of the Brazilian National Health Council, and the procedures were approved by the Local Ethics Committee following the Declaration of Helsinki.

The study included 72 physically active adult men (aged: 21 ± 4 years; body mass: 75 ± 12 kg). As inclusion criteria, the subjects were physically active (at least 150 min/week of moderate-intensity physical activity or 75 min/week of vigorous-intensity physical activity, or an equivalent combination of both), familiar with the push-up exercise, trained for a minimum frequency of three times per week, trained for at least three months without interruption, and had no positive response to any part of the PAR-Q (Thomas et al., 1992). The exclusion criterion was any health issue that could reduce performance or safety during the tests.

2.2. Procedure and Measurements

All participants completed the physical activity readiness questionnaire (PAR-Q) and underwent the bioimpedance assessment. Before the body composition evaluation, the participants were instructed to prepare in the following ways: a) fast for four hours (without ingesting any solid or liquid); b) urinate before the evaluation; c) not perform moderate or intense physical activity for 24 h before the evaluation; d) not consume caffeinated beverages for 24 h before the evaluation; and e) not use diuretic medication for 7 days before the evaluation (Guedes, 2013).

The participants subsequently performed both tests (upper-body WAnT or maximum interval push-up-MIPU test) in a single assessment session, with a 30-minute rest interval between them, to avoid the effects of the circadian rhythm. The order to begin the tests (WAnT or MIPU) was counterbalanced, following a 1:1 ratio, defined by lot using paper balls with a numbered sequence. Before the first physical test of the assessment session, a standard warm-up was performed using the inertial resistance of the equipment, consisting of 6 × 30 s bouts of alternated self-paced high- (20 s) and low-intensity (10 s). All the participants standardized and performed this warm-up. All tests were carried out by physical education professionals with the assistance of physical education students (Figure 1).

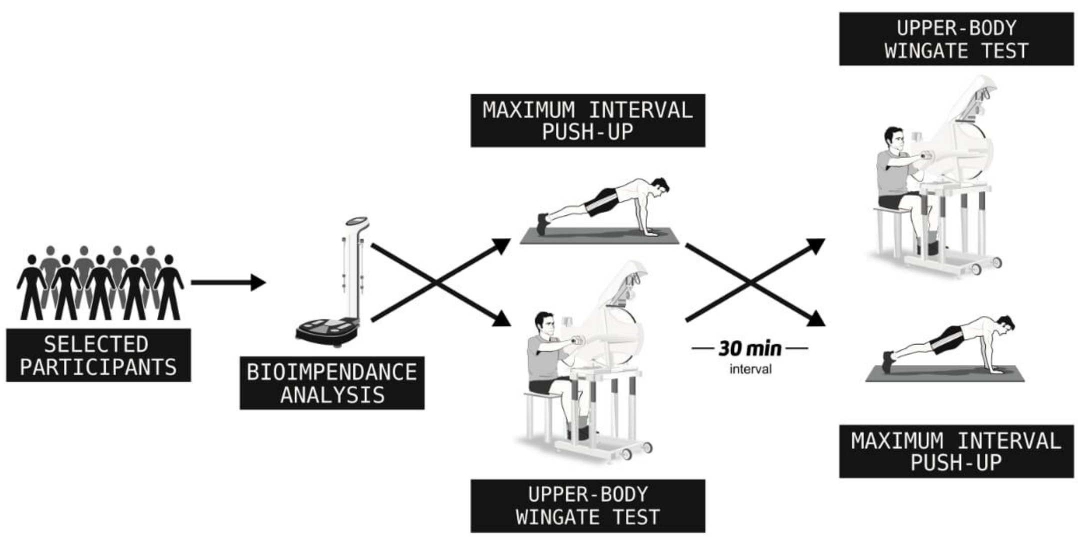

Figure 1. Schematic representation of the experimental protocol

2.2.1. Anthropometric measurements

Body mass and composition (absolute and relative body fat, muscle mass, lean mass, bone mass, and body water) were measured via a tetrapolar electroimpedance analysis multifrequency analyser with eight tactile points (InBody model 570; Biospace®, Seoul, Korea), which was evaluated in the orthostatic position, barefoot and with as little clothing as possible. Body composition analysis was conducted following the recommendations of the device manufacturer. Stature was measured via a stadiometer (model ES2040; Sanny, São Paulo, Brazil) coupled to the wall, which was evaluated in the orthostatic position, barefoot, with their ankles together, heels, buttocks, and shoulders touching the wall, and with the head in a neutral position, aligned with the spine (Lohman et al., 1988).

2.2.2. Upper-body Wingate test

The participants were then allowed a 3-minute interval before performing one upper-body WAnT from zero velocity and with the load set at the equivalent of 5% of each participant's body mass. Throughout the test, the researchers verbally encouraged the participants to maintain maximum effort. The body position was standardized, with participants seated on the cycle ergometer. The test was conducted via an EB 4100 cycle ergometer (Cefise, Nova Odessa, Brazil), connected to Ergometric 6.0 software (Cefise, Nova Odessa, Brazil), which recorded the power output parameters in real time. Power output was measured every 1 s. The highest value was considered the peak power, the mean value of the 30-s period was defined as the mean power, and the lowest value was considered the minimum power. The fatigue index was defined as the decline in power during the test (Franchini, 2019). The peak, mean, and minimum powers are expressed as absolute values (W) relative to body mass (W/kg). The fatigue index is expressed as a percentage of the peak power (%).

2.2.3. Maximum interval push-up (MIPU) test

The participants were instructed to perform the maximum push-ups within each exercise interval. For this purpose, the subjects began in a push-up position with their hands shoulder width apart, their elbows fully extended, their fingers pointing forward, and their feet together. The participants were instructed to keep their bodies straight, always maintaining a line between the hips and shoulders. The subjects lowered their body until their chest almost touched the floor (at least 90 degrees) and then pushed back to the starting position (Pollock & Wilmore, 1993). The supervisor visually validated each push-up by confirming that the subjects completed the full range of motion and maintained the correct posture. Common errors included not fully extending the elbows during the push-up or not maintaining a straight body alignment.

A total of six 6-second blocks of maximum repetitions were performed, interposed by 10-second intervals of passive recovery. The following commands were adopted: "prepare" 2 seconds before the start of each block and "start" and "stop" in each block. Only complete and correct repetitions performed in each effort block were considered in the analysis. To measure time at MIPU, a VL-510 stopwatch (Vollo®, São Paulo, Brazil) was used.

The anaerobic fitness indicators were determined on the basis of the number of repetitions of each block performed multiplied by body mass (rep*kg). The block with the highest power value of this multiplication was considered the peak power. The mean of the six blocks of effort was defined as the mean power. The lowest value was considered the minimum power. The fatigue index was defined as:

$$\text{Fatigue index (\%)} = \frac{(\text{peak power} - \text{minimum power}) \times 100}{\text{peak power}}$$

and expressed as a percentage (%).

2.3. Statistical Analyses

Data normality was assessed via the Kolmogorov–Smirnov test, which was selected on the basis of the sample size. Pearson's or Spearman's correlation coefficients were calculated to examine the relationships between variables, and correlations were classified as follows: trivial, 0.0 to <0.10; small, 0.10 to <0.3; moderate, 0.30 to <0.50; large, 0.50 to <0.70; very large, 0.70 to <0.89; nearly perfect, 0.90 to <0.99; and perfect, 1.0 (Hopkins, 2020). Pearson's correlation was applied to parametric data (data with a normal distribution), whereas Spearman's correlation was used for nonparametric data (data with non-normal distribution). The significance level was set at 5%. The data were analysed via the Statistical Package for Social Sciences software (version 20.0; IBM, United States of America).

3. RESULTS

Table 1 presents the results of the WAnT and MIPU assessments of the anaerobic power and capacity of the adult men.

Table 1. Anaerobic power and capacity of adult men in the upper-body Wingate Anaerobic Test (WAnT) and maximum interval push-up (MIPU) test (n= 72)

Variable	**WAnT**		**MIPU**
	Absolute (W)	**Relative (W/kg)**	**Relative (rep *kg)**
Minimum power	262 ± 121	3.5 ± 1,5	312 ± 215
Mean power	436 ± 116	5.8 ± 1.2	444 ± 191
Peak power	639 ± 169	8.4 ± 1.5	571 ± 190
Fatigue index (%)	57.2 ± 19.8	57.2 ± 19.8	49.7 ± 28.3

Note. *Data are presented as mean ± standard deviation*

In the MIPU test, the participants performed a total of 35 ± 14 rep (block 1: 7 ± 2 rep; block 2: 7 ± 2 rep; block 3: 6 ± 2 rep; block 4: 6 ± 3 rep; block 5: 5 ± 3 rep; and block 6: 4 ± 3 rep).

In the comparisons of the absolute values (W) obtained in the WAnT with those of the MIPU test (rep*kg), a very large correlation was observed for peak power, a large correlation for mean power, and a moderate correlation for minimum power (Figure 2).

A **B** **C**

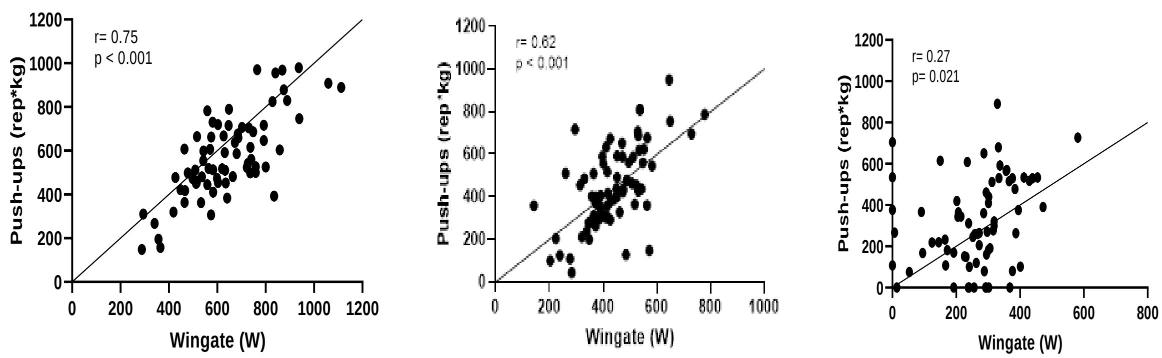

Figure 2. Association level between (PANEL A) peak power in the Wingate test (W) and peak power in the maximum interval push-up test (rep*kg), (PANEL B) mean power in the Wingate test (W) and mean power in the maximum interval push-up test (rep*kg), and (PANEL C) minimum power in the Wingate test (W) and minimum power in the maximum interval push-up test (rep*kg) (n= 72)

To compare the absolute values (W) obtained in the WAnT with those of the MIPU test (rep), a moderate correlation was observed for peak power, a moderate correlation for mean power, and a small correlation for minimum power (Figure 3).

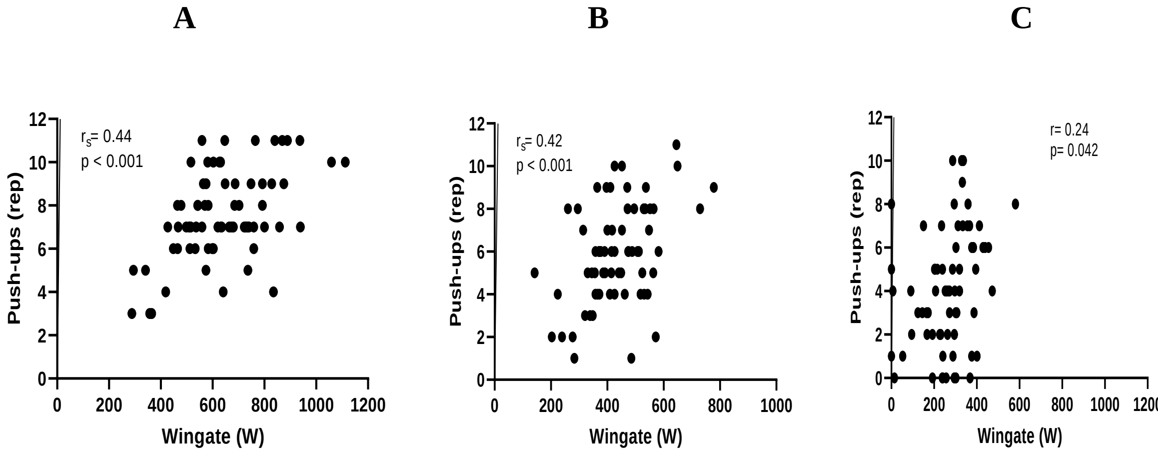

Figure 3. Association level between (PANEL A) peak power in the Wingate test (W) and peak power in the maximum interval push-up test (rep), (PANEL B) mean power in the Wingate test (W) and mean power in the maximum interval push-up test (rep), and (PANEL C) minimum power in the Wingate test (W) and minimum power in the maximum interval push-up test (rep) (n= 72)

When the relative values (W/kg) obtained in the WAnT were compared with those of the MIPU test (rep*kg), large correlations were observed for peak power and mean power, but no associations were found for minimum power (Figure 4).

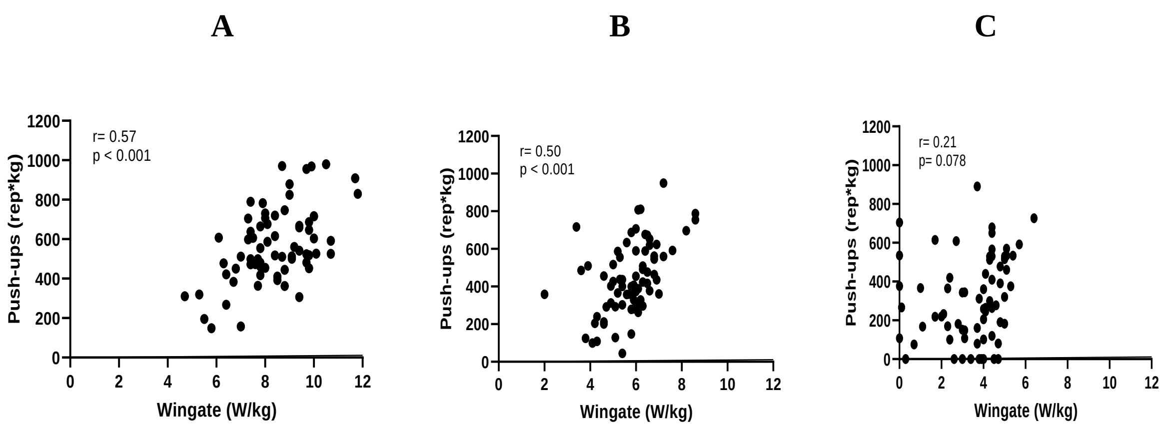

Figure 4. Association level between (PANEL A) peak power in the Wingate test (W/kg) and peak power in the maximum interval push-up test (rep*kg), (PANEL B) mean power in the Wingate test (W/kg) and mean power in the maximum interval push-up test (rep*kg), and (PANEL C) minimum power in the Wingate test (W/kg) and minimum power in the maximum interval push-up test (rep*kg) (n= 72)

Comparisons of the relative values (W/kg) obtained in the WAnT test to those of the MIPU test (rep) revealed large correlations for peak power and mean power and small correlations for minimum power (Figure 5). For the fatigue index, no associations were found for the results obtained from the WAnT and MIPU tests (r_s= 0.00; p= 0.894).

A **B** **C**

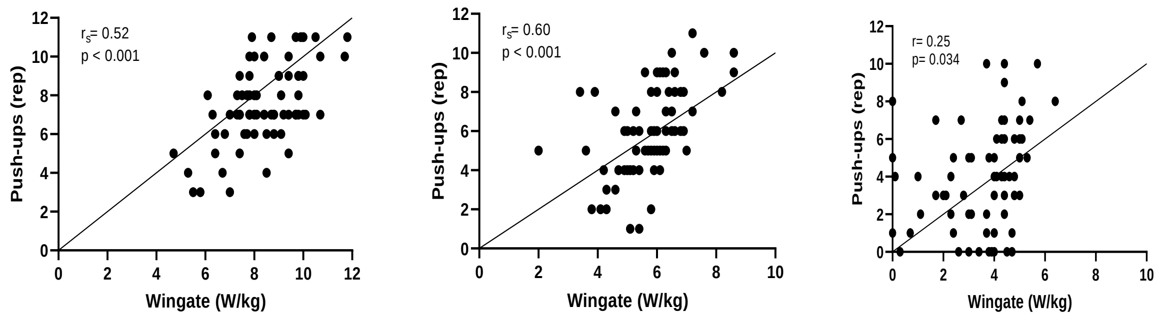

Figure 5. Association level between (PANEL A) peak power in the Wingate test (W/kg) and peak power in the maximum interval push-up test (rep), (PANEL B) mean power in the Wingate test (W/kg) and mean power in the maximum interval push-up test (rep), and (PANEL C) minimum power in the Wingate test (W/kg) and minimum power in the maximum interval push-up test (rep) (n= 72)

Absolute skeletal muscle mass (kg) and relative skeletal muscle mass (%) were associated with the total number of push-ups (rep) (r= 0.45, p<0.001 and r= 0.59, p<0.001, respectively), whereas relative skeletal muscle mass (%) was associated with the relative number of push-ups (rep*kg) (r= 0.64, p<0.001) in the MIPU test.

4. DISCUSSION

The current study was designed to develop and determine the concurrent validity of the alternative MIPU test to determine upper-body anaerobic power and capacity. The main results revealed a very large correlation for absolute peak power, a large correlation for mean power, and a large correlation for peak power and mean power between the WAnT (W) and MIPU (rep*kg) tests. Therefore, the MIPU was shown to be a practical field test that is easy to understand and has a low cost for assessing peak and mean upper-body power in physically active adult men.

For the validation process, concurrent validity, a criterion-related validity method in which correlation coefficients are calculated among a true criterion measure and an alternative measure, was used **(**Chaabene et al., 2018; Dobbin et al., 2021). Previous research has demonstrated the use of this method to determine the validity of new tests of upper-body power (Alves et al., 2015; Clemons et al., 2010; Dhahbi et al., 2015) and lower-body power **(**Chia & Lim, 2008; Samozino et al., 2016).

The results of the present investigation support previous findings, which led to the creation of alternative anaerobic power and capacity tests associated with WAnT measures (Alves et al., 2015; Clemons et al., 2010; Dhahbi et al., 2015; Janicijevic et al., 2019).

The main novelty of the present research was the inclusion of six 6-s blocks of maximum free repetitions, which provided experimental values closer to the WAnT results, with significant and large correlations for peak and mean power (r= ~0.6 and 0.5, respectively). The free repetitions of the push-up exercise were chosen because this is the most common upper-body exercise (Cetin et al., 2019; Clemons, 2019; Rogers et al., 2019) and is a very reliable and sensitive method for assessing upper-body endurance and isometric strength (Bellar et al., 2015; Clemons, 2019; Gillen et al., 2018). In addition, the low cost and popularity of the push-up exercise increases its ecological validity when composing a field test. Some differences emerge when comparing the MIPU test with other widely used upper-body anaerobic tests, such as the bench press power test and the medicine ball throw test. While the bench press and medicine ball throw tests primarily assess anaerobic power, the MIPU test uniquely evaluates both anaerobic power and capacity. Therefore, MIPU provides a valid and easily applicable alternative to other established tests.

The MIPU achieves this through free push-up repetitions, which are widely recognized exercises.

The literature on alternative upper-body evaluations indicates that systematic errors could occur in testing due to the selection and encouragement of one outcome or answer over others (Clemons et al., 2010). This subjective assumption has limitations that must be controlled to ensure better results between the WAnT and alternative measures, such as the MIPU test. The interpretation of bias cannot be limited to the question of whether it is present or absent from the new alternative test, but the WAnT has high internal validity for measuring capacity and anaerobic power (Chia & Lim, 2008; Coso & Mora-Rodriguez, 2006; Issurin et al., 2001; Leopold et al., 2019).

In comparison, the MIPU test also demonstrated significant correlations for peak and mean power, which supports its potential as a practical and valid field test for assessing upper-body anaerobic power and capacity. These findings suggest that the MIPU test could be a reliable alternative to more complex tests such as the WAnT for upper-body anaerobic performance. Unlike WAnT, which typically requires specialized equipment, the MIPU offers a more accessible and cost-effective option for a broader population. However, further investigation into the reproducibility of the test is needed to confirm its reliability across different evaluators and settings.

The present study considered the degree to which bias was prevented by using an adequate study design, concurrent validations, and implementing a practical upper-body test. Some degree of bias is almost always present in the study of open tasks; thus, future studies should consider how bias might influence the MIPU test findings. Bias in testing could stem from several factors, including participant motivation, measurement error in the push-up count, and inter- or intra-rater variability. Furthermore, the lack of standardization in the instructions or encouragement given by evaluators could also introduce bias into the results. It is important to address these factors to ensure that the MIPU test remains reliable and consistent across different settings and evaluators. There is little standardization of previous work in this field (Chan et al., 2019; Shusko et al., 2017), so method modifications between studies could be explored in future work. The present study highlights the improved internal validity of the WAnT results, which refers to the reliability or accuracy of the protocol used in upper-body anaerobic tests. Internal validity ensures that the study design, implementation, and data analysis confidently minimize bias and that the findings are representative of the true association between anaerobic profiles and test performance (Dexheimer et al., 2019).

Although the cycle ergometer is feasible for anaerobic tests for WAnT, one of the design limitations is that it lacks a technical facility to synchronize the application of the external resistance with the start of data collection (Attia et al., 2014; Janicijevic et al., 2019). This procedure is performed manually; if these two procedures are not performed simultaneously, the interval between the submission of the resistive load and the achievement of peak power will be compromised (Attia et al., 2014). Given this situation, it is difficult to control the accuracy of the time it takes for individuals to reach peak power with the WAnT; an extra challenge is that the measured peak power may not be exclusively characteristic of the physiological or attainable peak power (Bell & Cobner, 2007).

However, to date, few alternative tests of anaerobic performance have been performed with nonprofessional athletes and physically active men (Janicijevic et al., 2019; Shiroma et al., 2019), as these tests are more commonly used to assess athletes with specific skills, such as those performing gymnastics (Alves et al., 2015), judo (Shiroma et al., 2019), and climbing (Dhahbi et al., 2015). The absolute and relative number of push-ups in the MIPU test and skeletal muscle mass were significantly correlated. The analysis of the WAnT and MIPU test relationships allowed us to confirm our hypothesis; that is, the MIPU test of absolute and relative power output remained highly linear when modelled using the WAnT references, highlighting the large correlation between power output relative to an individual's weight and skeletal muscle mass.

Thus, the MIPU test could be a relevant tool to assist coaches and professionals involved in preparing athletes in the processes of evaluating, monitoring training, and preventing and rehabilitating injuries in athletes in sports where high-intensity upper-body actions are essential (e.g., handball, water polo, hockey, baseball, volleyball, boxing, judo, karate). The anaerobic power and capacity of the upper-body assessment have depended on the WAnT, which requires laboratory equipment that is financially inaccessible to many sports teams and some research laboratories. The MIPU, on the other hand, is a field test method that is easy to apply, easy to understand, and inexpensive, requiring few materials (mat and stopwatch).

As a limitation, the rater reproducibility and responsiveness were not tested. Another limitation of the MIPU is that evaluators must be well-trained to correctly give the commands during the test and only to count the correct movements. Thus, future research should evaluate the intra- and inter-rater reproducibility to test the applicability and reliability of this new field test and the responsiveness in different sports. Furthermore, MIPU should be investigated in the female population. Finally, considering the association between upper-body exercise capacity and future cardiovascular events (Yang et al., 2019), research involving training programs aimed at health promotion and rehabilitation can incorporate the MIPU test into their evaluation methods to verify its associations with health-related parameters.

5. CONCLUSIONS

In conclusion, the main results revealed a very large correlation for absolute peak power, a large correlation for mean power, and a large correlation for relative peak power and mean power between the WAnT and MIPU tests. Thus, the MIPU test can be considered an easy and practical field test for assessing peak and mean upper-body power in physically active adult men and could be used in the processes of evaluating, monitoring training, and preventing and rehabilitating injuries in athletes of sports where high-intensity upper-body actions are essential. In addition, the MIPU test could be introduced into health promotion and rehabilitation programs to monitor patient progress. However, it is necessary to consider that the MIPU intra- and inter-rater reproducibility still needs to be evaluated, as well as the MIPU test is not able to estimate the fatigue index, a fact that can be investigated in future research, which may require new reasons for effort:pause in the test structure.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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