KINESIOLOGY & COACHING

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Development and reliability of a kick test system for taekwondo athletes

Abstract

Background. the available anaerobic tests for taekwondo athletes consist of performing the maximum number of kicks in a fixed time-period. However, high-level athletes are characterized by small performance improvements.

Aim. The present study aims to develop a system that can count the number of kicks, and measure the time (in milliseconds) and to test its reliability. Additionally, we examined the possibility of using video-based method as a viable alternative.

Methods. The hardware system consisted of an analog accelerometer with three axes attached on the back of a kicking dummy, near the trunk region, that detected the occurrence of kicks. The sampling rate employed was 600 Hz per channel, and the resolution of the analog-to-digital converter was 10 bits for a voltage range of 0 to 3.3 Volts. The LabVIEW software was used to implement a routine with the interface of the task, as well as to process and store the collected data. Seventeen taekwondo athletes visited the laboratory on two different occasions, one week apart. Furthermore, in the first session, the performance assessment was filmed using a rate of 120 frames per second.

Results. The system developed was able to identify 100% of the kicks performed by the athletes, and demonstrated good absolute and relative reliability, and the video-based analysis can be used as a more viable tool to coaches and physical and conditioning professionals.

Conclusions. Our kick test system can be considered a reliable specific test for the assessment of high-intensity interval taekwondo-specific performance.

Introduction

Taekwondo is an intermittent striking combat sport characterized by kicks and punches actions (high-intensity efforts) interspersed with periods of non-fighting activity (low-intensity) at average ratios between 1:2 and 1:7 [Bridge *et al.* 2009; Tayech *et al.* 2019]. In the competition, the main actions executed during taekwondo matches are kicks directed to the opponent's trunk, and the main technical action used by the athletes is the roundhouse kick, also called *bandal tchagui* by taekwondo practitioners [Kazemi *et al.* 2006].

As reported previously by Campos *et al.* [2012], the taekwondo match is predominantly oxidative (66 ± 6%), although the phosphagen (30 ± 6%) and glycolytic (4 ± 2%) systems support the scoring actions (e.g., kicks and punches). Therefore, most of the scoring actions are characterized by short-duration high-intensity actions lasting around 1-2s [Bridge *et al.* 2009; Matsushigue *et al.* 2009; Santos *et al.* 2011] and relies predominantly on the phosphagen system. Thus, tests evaluating the speed of taekwondo-specific techniques or the anaerobic system during its execution are relevant to provide valuable information concerning the effects of training programs

or other interventions (e.g., nutritional supplementation, warm-up procedures, psychological activation) on this key performance variable.

To the best of our knowledge, the available anaerobic tests for taekwondo athletes consist of performing the maximum number of kicks in a fixed time-period [Rocha *et al.* 2016; Sant'Ana *et al.* 2014; Santos *et al.* 2015; Tayech *et al.* 2019]. For example, a commonly used test called Frequency Speed of Kick Test (FSKT) is performed in two forms, the first composed of one 10s set and the second of five 10s sets with 10s of rest intervals between sets. Variables generated are kick number in each set, total kick number (sum of kicks performed in the all sets), and kick decrement index [Santos, Franchini 2018; Santos *et al.* 2015]. In addition, FSKT has been reported to be reliable [Santos *et al.* 2018], sensitive to taekwondo-specific training [Santos, Franchini 2016] and able to proper discriminate female taekwondo athletes from different competitive levels [Santos, Franchini 2018]. However, high-level athletes are characterized by small performance improvements [Malcata, Hopkins 2014] in response to training and other intervention processes. Thus, tests with higher accuracy are needed to detect these small changes. For example, using the hypothetical example presented in the Figure 1, one athlete executed the 10s FSKT pre-training A (Figure 1a) and post-training (Figure 1b). In both moments the athlete performed 18 kicks, but in the pre-training, he was far from the completion of a new repetition, whereas post-training he was closer to performing the 19th kick. Thus, with a more precise unit of measure (for example, milliseconds) the test could have greater capacity for identifying small changes.

In addition, due to the speed attained during the execution of the kicks in the FSKT, it is necessary to film the test for later analysis for a more accurate assessment, which can be easily driven by a low-cost camera (e.g. GoPro Hero 5) and open-license and easy-to-use video analysis software (i.e., Kinovea 0.8.15 for Win-

dows; available at http://www.kinovea.org) or to use a high cost electronic protector [Santos *et al.* 2015; Tayech *et al.* 2019]. Thus, modifying the analysis of the number of kicks taken in a fixed time-period (e.g., 5 or 10 seconds) to the time required to perform a fixed number of kicks (e.g., 20 kicks) has few implications in the analyses and can give the test higher precision. However, it does not affect the problem of the time demand needed to obtain the result.

In this way, developing a system that is capable of counting the number of kicks, measuring the interval between kicks (in milliseconds), controlling the pause time between series, and providing the results quickly can contribute to a more precise measurement and that can be of great value to coaches and physical and conditioning professionals.

Thus, the aims of the present study were: 1) to develop a system that is able to count the number of kicks, measure the time (in milliseconds) to perform a fixed number of kicks, control the pause time between sets, and provide the results quickly; 2) to test the reliability of the system developed; and 3) to test the possibility to use video-based method as a viable alternative.

Methods

Participants

Seventeen black belt taekwondo athletes (15 men, 2 women; mean ± SD, age: 19.53 ± 6.00 years; body mass: 68.34 ± 13.08 kg; height: 175.53 ± 7.31 cm; practice time: 5.94 ± 4.26 years; competitive level: international/national) volunteered to participate in this study. The athletes participated in approximately seven taekwondo-specific training sessions and three strength-training sessions weekly. The athletes reported to be free from mental disorders and injuries in the lower body and were not engaged in any rapid acute weight loss strategy during the study period. The participants were informed

a) Pre-training   b) Post-training

Figure 1. Hypothetical example where a) represents pre-training and b) post-training

about the procedures and possible risks before signing the written informed consent. The research was approved by the local Research Ethics Committee (approval number: 03516418.1.0000.5149), in accordance with the Declaration of Helsinki.

Developed system

The first stage was to develop the hardware and software able to identify and count the number of kicks taken to perform the task and measure the time interval between kicks in milliseconds. The hardware system (Figure 2) consists of an analog accelerometer with 3 axes (model ADXL 335), that allows detecting the occurrence of kicks. The accelerometer was attached with tape on the back of the kicking dummy (Boomboxe, Sao Paulo, Brazil), near the trunk region. A 5-way 2-m long cable (3.3 V, GND, x-axis, y-axis and z-axis) was used to connect the accelerometer to Arduino board (Arduino Pro-Mini - ATMega 328 microcontroller, 8 MHz clock), which scans the analog signals from the 3 axes of the accelerometer and sends them to a computer. The sampling rate employed is 600 Hz per channel and the resolution of the analog-to-digital converter is 10 bits for a voltage range of 0 to 3.3 Volts (quantization of 3.2 mV, which seems to be enough for analysis of the accelerometer signals). A notebook (2.5 GHz i5 processor with 8 GB of RAM installed) has been made available for processing data sent from Arduino Pro-Mini board and for displaying a user interface (Figure 2). Communication between Arduino Pro-Mini board and this notebook is done by means of a UART to USB converter (CP2102 module), since the Arduino board used does not have embedded USB communication interface. Power supply for the system components (accelerometer, Arduino board and CP2102 module) comes from the notebook's own USB port, with no need for batteries or other dedicated sources.

LabVIEW (2011 licensed version) was used to implement a routine with interface of the task, as well as processing and storing the collected data. At each sampling interval, this routine receives three samples sent by the Arduino board, referring to the accelerations in each axis of the accelerometer. Each sample is a value from 0 to 1023 (Arbitrary Units), since the analog-to-digital converter used has 10-bit resolution. It is worth noting that there is no need to transform the values of these samples to some absolute value in m/s² or a value relative to acceleration of gravity, because the aim of the system is to detect the exact moment in which each kick hits the dummy, and this does not depend on the unit of measurement. Thus, the system measures the total acceleration by adding the squares of the samples on each axis. This measure can be called a[k], where k Î {1, 2, 3, ...} indicates sample number or sampling instant. To attenuate low-frequency oscillations, eliminate offsets, and make the signal always positive, the routine also calculates a measure y [k], subtracting from a[k] the previous value of that measurement and calculating the result module. The equations are below:

$$a[k] = x^2[k] + y^2[k] + z^2[k]$$
$$y[k] = |\, a[k] - a[k\text{-}1]\,|$$

Specifically, the accelerometer records acceleration variations reflecting directly on the measure y[k]. Thus, the algorithm for detecting kicks consists of comparing the value of this measure to a previously established threshold. If it exceeds this threshold, a kick is considered to have occurred. After several tests with athletes, the value of 200 (a.u.) was used as threshold.

In addition to an initial peak in the signal y [k], each kick still causes many other acceleration (post-kick noise), due to the return movement of the kicking
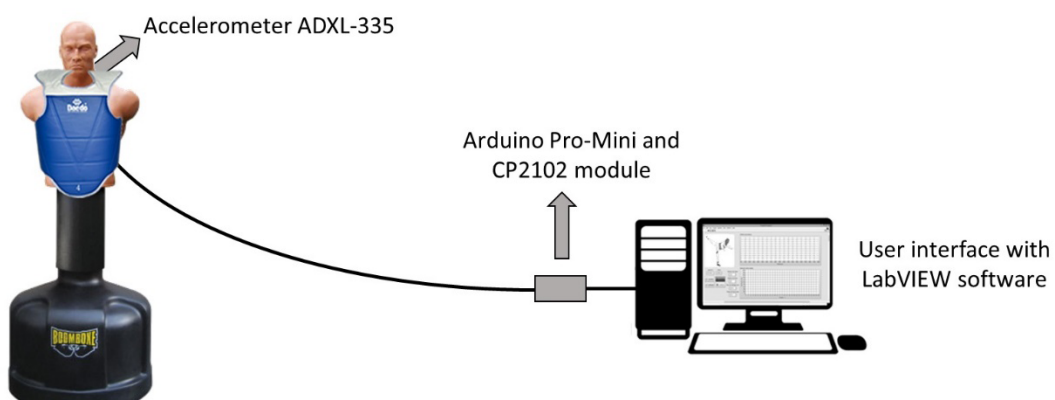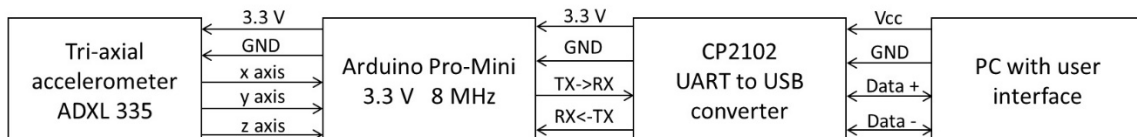

Figure 2. Overview of hardware components for the proposed system

dummy to its rest position. In addition, not infrequently these peaks (noise) exceed the threshold set for the kick detection algorithm, which means that the routine would be subject to many false positives. One solution that satisfactorily circumvents this problem is to consider the natural dynamics of the kicking process of athletes. Thus, after the initial peak of y [k], the routine ignores any events detected in the next 399 milliseconds (value chosen after many tests), since it is unlikely that an athlete would be able to hit the kicking dummy twice in less than 400 ms, correctly executing the movement of the *bandal tchagui*. Regarding the occurrence of false negatives (when the athlete's kick does not cause a peak greater than 200 in the signal y [k]), it was practically non-existent in the tests performed.

Figure 3 shows an excerpt of signal y [k] with 1 second duration, obtained during a real test with an athlete. In this interval, the athlete kicked the dummy twice, and the signal y [k] is showed. Thus, the post-kick vibrations have sometimes exceeded the threshold for kick detection, but as explained earlier, the implemented filter (399 ms) rejects these occurrences.
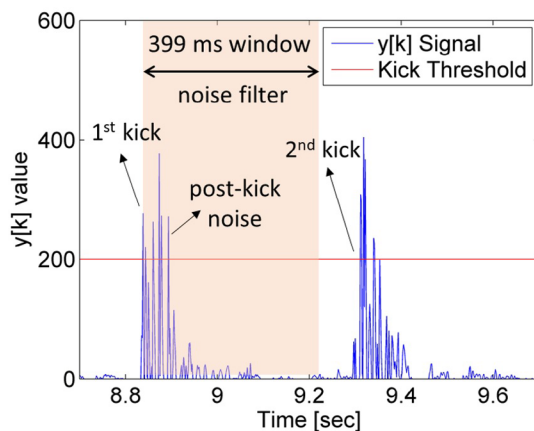
Figure 3. Signal y [k] obtained during the real test example with an athlete

Note: When the value of y [k] (blue curve) exceeds the threshold (red curve), a kick is considered to have occurred. Post-kick vibrations may exceed this threshold, but in a 399 ms window after the initial peak, these oscillations are rejected and are not interpreted as kicks.

In the end, the system needs to be able to control the effort and pause ratio of the test. For this, we implemented a sound system that is presented at the beginning and end of each of the effort and pause sequences.

Performance Assessments
The subjects started by warming-up and then performed the Kick test.

Warm-up: The subjects performed 5 minutes of warm-up consisting of 2 minutes of stepping and displacements according to the taekwondo-specific techniques and 3 minutes of low-intensity taekwondo kicks.

Kick Test: After a sound signal, the athletes had to perform 20 kicks as fast as possible, alternating right and left legs. The technique used was the *bandal tchagui*. The test consists of 5 sets of 20 kicks with 10 seconds of passive rest between sets, performed in a kicking dummy (Boomboxe, Sao Paulo, Brazil) equipped with a taekwondo body protector (Protector, Daedo). The performance was determined by the interval of time in milliseconds between the 1st kick and the 20th kick by the set, total time (sum of times in milliseconds in the all sets) and time increased index by the equation below.

$$Equation 1 : [) - 1] \times 100$$

Rating of Perceived Exertion (RPE): The CR-10 RPE-scale proposed by Borg (1982) was used to evaluate the athletes' perceived exertion. The subjects had to report their RPE at the end of the fifth set of the Kick test.

Procedures
The participants visited the laboratory on two different occasions. As the athletes selected in the present study frequently used the FSKT [Mesquita *et al.* 2019] in their training routine, and which is technically very similar to our kick test, the familiarization with the study protocols was not performed. Thus, in the first session, the athletes signed the consent form and answered a questionnaire about their competitive level and training routines, and had their body mass, and height measured. As conducted by our laboratory previously [Mesquita *et al.* 2019], at the beginning of the experimental procedures, the subjects should report their Rating of Perceived Recovery (RPR). The RPR scale proposed by Laurent *et al.* (2011) was used to control for a possible influence of the recovery status on the performance outcomes between experimental sessions.

In each session of the experimental procedures, the subjects executed performance assessment by the Kick Test. Additionally, the subjects reported their rating of perceived exertion (RPE) in the end of the test, using the 0-10 Borg scale. The experimental sessions were performed at the same time of the day and were interspaced by 1 week. The subjects were instructed to avoid caffeine and alcohol consumption and strenuous exercise for 48h before each visit. The procedures performed are illustrated in Figure 4. In the first session, the performance assessment was filmed by a Camera GoPro hero 5 with sampled images by the rate of 120 frames per second.

Statistical analysis
Data were tested for normal distribution using the Shapiro-Wilk's test. For the variables in which the assumptions of normality were found, means, standard deviations (SD), and coefficient of variations (CV) were used. On the other hand, for variables in which the
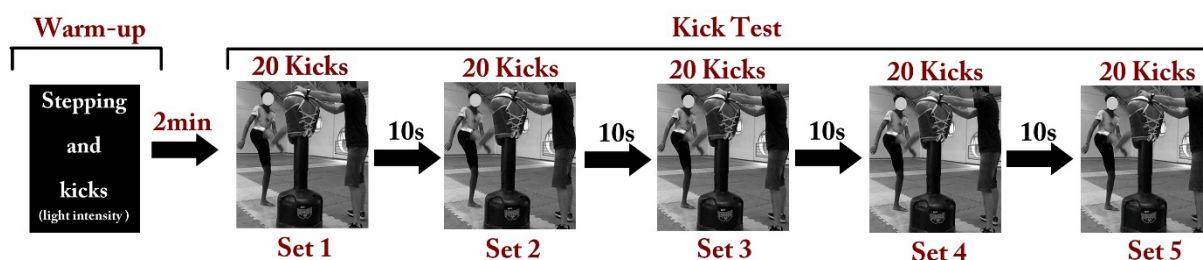
Performance Assessments

Figure 4. Procedures of the experimental session

assumptions of normality were not found, median and 95% confidence interval were used.

Relative reliability was assessed using the intraclass correlation coefficient (ICC). ICC estimates and their 95% confident interval were calculated based on single measurement absolute-agreement, 2-way mixed-effects model. Moreover, as suggested previously [Koo, Li 2016], ICC values less than 0.50 are indicative of poor reliability, values between 0.50 and 0.75 indicate moderate reliability, values between 0.75 and 0.90 indicate good reliability and values greater than 0.90 indicate excellent reliability.

To assess absolute reliability, as used previously [Franchini *et al.* 2018; Darrall-Jones *et al.* 2016], we used typical error of measurement (TEM). The usefulness of the test was assessed by comparing the smallest worthwhile change (SWC) and the TEM. The SWC was assumed by multiplying the between-subject standard deviation in section 1 by 0.2 (SWC 0.2) indicating the typical small effect, 0.6 (SWC 0.6), indicating moderate effect, and 1.2 (SWC 1.2), indicating a large effect (15). The ability of the test to detect a change was rated as "good", "OK", or "marginal" when the TEM was below, similar or higher than the SWC, respectively. The minimal detectable change (MDC95%) of the Kick Test which represents 95% CI of the difference in score between paired observations was determined as MDC95%= TEM×1.96×√2. In addition, Person's correlation was used, and all analyses were performed in RStudio.

Results

Reliability's results are displayed in Table 1. The ICC value was higher than 0.60 (range from 0.601 to 0.834) in all sets and for the total time measurement (that indicate moderate to good reliability). Conversely, the time increased index (%) ICC value was 0.409, indicating a poor reliability. The TEM was lower than SWC 1.2 in time increased index measure and lower than SWC 0.6 and SWC 1.2 for other measures. In addition, the MDC95% ranged from 905 (set 1) to 1463 (set 5) milliseconds for sets, 4266 and 8.12 for total time and time increased index, respectively.

The RPE measured in both sessions [Median of RPR in 1st session = 10 (interquartile range = 1) and Median of RPR in 2nd session = 10 (interquartile range = 1)] showed no significant differences [z = 0.000, p = 1.000; ES = .00 (low)]. In addition, RPR did not differ [z = 0.095, p = .949; ES = .02 (low)] between sessions [Median of RPR in 1st session = 8 (interquartile range = 2) and Median of RPR in 2nd session = 8 (interquartile range = 3)].

As our system has a higher sampling rate (600Hz) than video-based method (120Hz) it will be used as a reference method (gold standard). The agreement between the system and the Kinovea by Bland and Altman plots are shown in Table 2, with a low mean bias between the system and the Kinovea. In addition, Table 2 shows mean, standard deviation, and Pearson's correlations of the measurements of Kick Test and Video-Based Analy-

Table 1. ICC, Typical Error of Measurement, $SWC_{0.2;0.6; and 1.2}$ and $MDC_{95\%}$ of Test and Retest sections

Variables	ICC (95% IC)	TEM	$SWC_{(0.2)}$	$SWC_{(0.6)}$	$SWC_{(1.2)}$	$MDC_{95\%}$	CV test	CVretest
Set 1 (ms)	0.834 (0.608 - 0.936)	326 (243 – 497)	155	466	932	905	8.24%	8.77%
Set 2 (ms)	0.768 (0.454 - 0.910)	360 (268 – 548)	149	447	895	998	7.67%	7.36%
Set 3 (ms)	0.793 (0.515 - 0.920)	363 (270 – 552.19)	151	453	905	1006	7.37%	8.67%
Set 4 (ms)	0.736 (0.389 - 0.897)	432 (322 – 658)	151	454	908	1198	7.06%	9.37%
Set 5 (ms)	0.601 (0.147 - 0.839)	528 (393 – 803)	142	428	855	1463	6.48%	9.54%
TT (ms)	0.801 (0.451 - 0.929)	1539 (1146 – 2342)	713	2139	4278	4266	6.98%	8.03%
TII (%)	0.409 (-0.058 - 0.734)	3 (2 – 5)	1	2	3	8	31.55%	47.70%

Note: TT - Total Time; TII - Time Increased Index

Table 2. Mean, standard deviation, Pearson's correlations, and Bland and Altman Stats of system and video-based analysis

Variables	Kick Test Mean (± SD)	Video-Based Analysis Mean (± SD)	Pearson's Correlation	Bland and Altman Stats	
				Mean Bias	Lower (95%CI)
Set 1 (ms)	9420 (± 776)	9436(±782)	1.00 (p < 0.001)	-15.76	-140.59
Set 2 (ms)	9719 (± 746)	9741 (± 754)	1.00 (p < 0.001)	-22.53	-119.58
Set 3 (ms)	10237 (± 754)	10261 (± 766)	1.00 (p < 0.001)	-23.94	-155.60
Set 4 (ms)	10711 (± 756)	10738 (±765)	1.00 (p < 0.001)	-27.24	-176.30
Set 5 (ms)	11006 (± 713)	11031 (±711)	0.98 (p < 0.001)	-24.41	-314.90
TT (ms)	51094 (± 3565)	51208 (± 3602)	1.00 (p < 0.001)	-113.88	-771.29
TII (%)	9 (± 3)	9 (± 3)	0.99 (p < 0.001)	-0.01	-0.97

Note: TT - Total Time; TII - Time Increased Index

sis, in which significant, positive and strong correlations (see Table 2) were found between the Kick Test and the video-based analysis.

Discussion

The primary aim of the present study was to develop a system that can count the number of kicks, measure the time (in milliseconds) to perform a fixed number of kicks, control the pause time between sets, and provide the results quickly. In addition, we aimed to determine the reliability of the kick test developed, and to verify the possibility to use a video-based method as an alternative to modify the unit of measurement of the FSKT.

Our first relevant result was that the system developed by us was able to identify 100% of the kicks performed by the seventeen athletes investigated, using 200 (a.u.) as threshold and 399 ms as latency time between kicks. In other words, using these parameters, no false positives or negatives were detected in our sample. This point is of fundamental importance for the use of the system because any false negative or positive detected would modify the operations of the system and would interfere in the quality of the system. In addition, the use of a sampling rate of 600Hz ensures considerable system accuracy.

The time to perform 20 kicks in the system developed by us ranged from 9.4s to 11.0s. As most of the available anaerobic tests for taekwondo athletes consist of performing the maximum number of kicks in a fixed time-period [Tayech *et al.* 2019; Rocha *et al.* 2016; Sant'Ana *et al.* 2014], it is not possible to compare our results to existing literature. However, the time to perform the kicks found in our study is close to the 10-seconds sets originally used in the FSKT [Santos, Franchini 2016; Santos, Franchini 2018; Santos *et al.* 2015]. In addition, the usual decrement in performance observed throughout the sets in FSKT was also observed in our test. In addition, the high values for RPE observed confirm the high-intensity characteristic of the test. Therefore, it seems safe to assume that our modifications did not

change the main characteristics and energetic demands of the FSKT.

Reliability analysis reports the ability of a testing protocol to provide measurements that can be replicated, in other words, the consistency of measurements of the test [Atkinson, Nevill 1998; Koo, Li 2016; Weir 2005]. AtkinsonNevill (1998) have reported two types of reliability: relative reliability and absolute reliability. Relative reliability refers to the degree to which repeated measurements vary for individuals (consistency of scores of individuals) and the intraclass correlation coefficient (ICC) is a statistical method used to this purpose [Impellizzeri, Marcora 2009; Atkinson, Nevill 1998]. Previous studies conducted with combat sports kicking tests have found ICC of 0.89-0.99 [Rocha *et al.* 2016], and 0.71-0.85 [Araujo *et al.* 2017]. Our results showed that ICC values were higher than 0.60 (range from 0.601 to 0.834) in all sets and in total time measure, that indicate moderate to good reliability. Nevertheless, the time increased index (%) ICC value was 0.409, indicating a poor reliability. A possible explanation of the poor reliability values of the Time Increased Index is that the ICC is affected by sample heterogeneity [Weir 2005; Schuck 2004], as showed in high values of the coefficient of variation in time increased index measure. Carrying out a supplementary analysis by the power analysis of the ICC using the "ICC.Sample.Size" packages in R, our results showed a power of 0.997; 0.982; 0.990; 0.965; and 0.794 for the set 1 to 5 respectively, and 0.993 for total time and 0.412 for time increased index, indicating that our results have considerable power for the measures, with the exception of the time increased index.

Absolute reliability refers to the degree to which individuals maintain their position in a sample with repeated measurements in which typical error of measurement (TEM) is used for evaluative tests to monitor changes over time [Atkinson, Nevill 1998; Impellizzeri, Marcora 2009]. In addition, Hopkins (2019) proposed that when TEM is higher than SWC, the evaluation of the variable being used was "marginal", when TE was similar to the SWC, it was "medium;" and if TEM was less than the SWC, an evaluation of "good" was given to the

test to detect small (0.2), medium (0.6), and large (1.2) differences. In summary, the TEM was lower than both SWC 0.6 and SWC 1.2 for all measures except for time increased index, which was smaller only than SWC 1.2, indicating that our measures only allow for the detection of large changes in time increased index and medium and large changes for all other measures. A recent systematic review [Lopes-Silva *et al.* 2019] regarding repeated sprint ability tests indicated that fatigue index was not a reliable variable (coefficient of variation between 14.4 and 52.0% and TEM between 0.38 and 22.5%). As this kind of variable is influenced by both the peak and lowest performance it seems to carry the error of the two of them in its calculation. In the end, it is important to note that the SWC 0.6 values are within the 95% confidence interval of TEM, and these results should be interpreted with caution. On the other hand, SWC 1.2 is higher than TEM of all measures except for time increased index.

Thus, our results showed that the system developed by us presented good absolute and relative reliability, which in turn makes it a good alternative for the FSKT with a more precise measure. However, we understand that this is a complex system that needs specific equipment and software, which might not be available to many coaches and athletes. Besides specificity, feasibility is also an important aspect in performance testing for combat sports [Chaabene *et al.* 2018]. In that direction, our results also showed low mean bias (or high agreement), and positive and strong correlations between the time recorded by our system and the one retrieved by video-based analysis. Therefore, using a low-cost camera and open-license and easy-to-use video analysis software, it is possible to give the test higher precision. In addition, the need to film the test for later analysis is a common practice in previous test (e.g., FSKT). Thus, modifying the analysis to the time required to perform a fixed number of kicks (e.g., 20 kicks) has few feasibility implications while giving the test a higher precision. Therefore, the video-based analysis is a good alternative to the kick system and might be a more viable tool to coaches and physical and conditioning professionals.

Conclusions

In conclusion, our study showed that the kick test system can be considered a reliable specific test for the assessment of high-intensity interval taekwondo-specific performance. Combat sports that share similar characteristics, such as kickboxing and Muay-Thai could also benefit from it. In addition, the video-based analysis was shown to be a good alternative for the daily activities of coaches and staff involved in the performance assessment of athletes.

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Rozwój i niezawodność systemu testowania kopnięć zawodników *taekwondo*

Słowa kluczowe: sporty walki, sprawność anaerobowa, wydajność, test specjalny

Abstrakt

Tło. Testy beztlenowe dostępne dla zawodników taekwondo polegają na wykonaniu maksymalnej liczby kopnięć w ustalonym czasie. Jednak sportowców na wysokim poziomie zaawansowania charakteryzuje niewielka poprawa wyników. Problem i cel. Celem niniejszych badań było opracowanie systemu, który może zliczać liczbę kopnięć, mierzyć czas (w milisekundach) i testować jego niezawodność. Dodatkowo

zbadano możliwość wykorzystania metody wideo jako realnej alternatywy

Metody. Sprzęt składł się z analogowego przyspieszeniomierza z trzema osiami zamocowanymi z tyłu manekina, w okolicy tułowia, który pozwala na wykrycie występowania kopnięć. Zastosowana częstotliwość próbkowania wynosiła 600 Hz na kanał, a rozdzielczość przetwornika analogowo-cyfrowego wynosiła 10 bitów dla zakresu napięć od 0 do 3,3 Volta. Oprogramowanie LabVIEW zostało wykorzystane do realizacji procedury z interfejsem zadania, jak również do przetwarzania i przechowywania zebranych danych. Siedemnastu zawodników taekwondo odwiedziło laboratorium przy dwóch różnych okazjach, z tygodniową przerwą pomiędzy nimi. Ponadto, w pierwszej sesji, ocena wydajności została sfilmowana z prędkością 120 klatek na sekundę.

Wyniki. Opracowany system był w stanie zidentyfikować 100% kopnięć wykonanych przez zawodników. Wykazał się on dobrą bezwzględną i względną wiarygodnością, a analiza na podstawie wideo może być wykorzystana jako bardziej opłacalne narzędzie dla trenerów i profesjonalistów z dziedziny wychowania fizycznego i kondycji.

Wnioski. System testów kopnięć zbadany przez autorów może być uznany za wiarygodny test specjalny dla oceny wysokiej intensywności interwału w taekwondo.