2024, Retos, 61, 706-713

Intra-test reliability of the countermovement push-up and its relationship with anthropometric parameters in semi-professional kickboxers

Fiabilidad intraprueba de la flexión de brazos con contramovimiento y su relación con parámetros antropométricos en kickboxers semiprofesionales

*Pablo Merino-Muñoz, **,*****Felipe Guimarães Teixeira, ***Jorge Pérez-Contreras, ***Felipe Inostroza-Rios, **Aleksandro Ferreira, *,****Ciro Brito, **Bianca Miarka, *Esteban Aedo-Muñoz

*University of Santiago of Chile (Chile), **Federal University of Rio de Janeiro (Brasil), ***Universidad Santo Tomas (Chile), ****Federal University of Juiz de Fora (Brasil), *****University of Estácio de Sá (Brasil)

Abstract. Objective: This study aimed to investigate the intra-test reliability of countermovement push-up (CMPU) in semi-professional kickboxing athletes and to analyze the association with anthropometric measurements of the upper limb. Methods: 8 semi-professional kickboxing athletes (7 male and 1 female athletes) underwent a series of assessments, including skinfold thickness, limb circumference measurements, and the CMPU test with force platforms. Intraclass correlation coefficients (ICC) and coefficients of variation (CV%) were calculated for CMPU variables. Additionally, Spearman correlation coefficients were computed to assess the relationship between upper limb anthropometric data and CMPU variables derived from the force platform. Results: The ICC and CV% values indicated that the analyzed performance variables exhibited reliability ranging from poor to excellent (ICC = 0.65–0.77, CV% = 5.6–20.8). Push-off time and rate of power development concentric demonstrated unclear reliability (ICC = 0.15–0.31, CV% = 7.5–14.9), while rate of force development braking showed poor to good reliability (ICC = 0.44, CV% = 27.4). Strong to very strong correlations were observed between relaxed arm circumference, contracted arm circumference, forearm circumference, bicipital fold, and concentric impulse, peak force, and peak power. Conclusion: The results of this study emphasize the reliability of CMPU testing in semi-professional kickboxing athletes, making it a potentially valuable tool for monitoring upper limb force and power variables. Additionally, the robust correlations suggest that variations in upper limb circumference can significantly influence force and power generation during the CMPU test. These findings have implications for training program design and performance assessment in activities reliant on upper body strength and power, such as kickboxing.
Keywords: biomechanics, kinetic, kinematic, martial arts, combat sport.

Resumen. Objetivo: El objetivo del estudio fue investigar la confiabilidad intraprueba de las flexiones con contramovimiento (CMPU) en atletas semiprofesionales de kickboxing y analizar la asociación con las mediciones antropométricas del miembro superior. Métodos: 8 atletas semiprofesionales de kickboxing (7 hombres y 1 mujer) se sometieron a una serie de evaluaciones, que incluyeron pliegues cutáneos, circunferencia de las extremidades y la prueba CMPU en plataformas de fuerza. Se calcularon los coeficientes de correlación intraclase (ICC) y los coeficientes de variación (CV%) para las variables CMPU. Además, se calcularon los coeficientes de correlación de Spearman para evaluar la relación entre los datos antropométricos de las extremidades superiores y las variables CMPU derivadas de la plataforma de fuerza. Resultados: Los valores de ICC y CV% indicaron que las variables de rendimiento analizadas exhibieron una confiabilidad que oscilaba entre pobre y excelente (ICC = 0,65–0,77, CV% = 5,6–20,8). El tiempo de impulso y la tasa de desarrollo de potencia concéntrica demostraron una confiabilidad poco clara (ICC = 0,15–0,31, CV% = 7,5–14,9), mientras que la tasa de desarrollo de fuerza de frenado mostró una confiabilidad de pobre a buena (ICC = 0,44, CV% = 27,4). Se observaron correlaciones fuertes a muy fuertes entre la circunferencia del brazo relajado, la circunferencia del brazo contraída, la circunferencia del antebrazo, el pliegue bicipital y el impulso concéntrico, la fuerza máxima y la potencia máxima. Conclusión: Los resultados de este estudio enfatizan la confiabilidad de las pruebas CMPU en atletas semiprofesionales de kickboxing, lo que las convierte en una herramienta potencialmente valiosa para monitorear las variables de fuerza y potencia de las extremidades superiores. Además, las correlaciones fuertes sugieren que las variaciones en la circunferencia de las extremidades superiores pueden influir significativamente en la generación de fuerza y potencia durante la prueba CMPU. Estos hallazgos tienen implicaciones para el diseño de programas de entrenamiento y la evaluación del desempeño en actividades que dependen de la fuerza y potencia de la parte superior del cuerpo, como el kickboxing.
Palabras clave: biomecánica, cinética, cinemática, artes marciales, deporte de combate.

Fecha recepción: 23-07-24. Fecha de aceptación: 17-09-24
Esteban Aedo-Muñoz
esteban.aedo@usach.cl

Introduction

Kickboxing is a combat sport characterized by intermittent variations in intensity and complex technical and tactical skills (Slimani et al., 2016). This combat sport aims to strike the opponent with strength and speed (Slimani, Chaabene, Miarka, Franchini, et al., 2017). During combat, athletes perform punch and kick techniques to knock out the opponent and thus end the fight (Ambroży et al., 2020). Punching is an explosive action performed by the upper limbs (Chaabène et al., 2015), with variations in execution techniques such as the jab, direct punch, cross, hook, and spinning punch (Ambroży et al., 2020). In addition to technical mastery, the effectiveness of a punch depends on the strength, power, speed, flexibility and resistance of the athlete's upper limbs (El-Ashker, 2018). Therefore, research which explores the intra-test reliability of the countermovement push-up (CMPU) is essential, as it is a crucial measure of upper limb power in semi-professional kickboxers, where muscle strength and power are key performance factors. In addition, no one study had study examined the relationship between CMPU performance variables and anthropometric measurements of the upper limbs. Considering that weight categorization is crucial in kickboxing and an inadequate weight loss strategy can negatively influence strength and power production (Martinez-Aranda et al., 2023), understanding the association between these variables becomes even more relevant.

Among the important physical abilities for the kickboxing athlete, muscle power is a key factor for sports performance and athletic ability (Hogarth et al., 2013; Parry et al., 2020), especially in the upper limbs. Therefore, evaluating the muscular power of these athletes is necessary to identify the level of this physical capacity, monitor the effects of the training program and the fatigue levels (Hogarth et al., 2013). To carry out this evaluation, some coaches use the medicine ball throw test, the bench press test and the timed arm flexion test (Borms et al., 2018). However, these tests measure work-related variables rather than power (Parry et al., 2021), highlighting the need for a gold standard test to assess upper limb power in kickboxing athletes.

A promising test to obtain power information from the upper limbs is countermovement push-off (CMPU) performed on the force platform. The test starts with the subject with trunk, legs and elbows extended and shoulder at 90º with hands resting on the force platform, at the evaluator's signal the participant lowers the trunk quickly towards the force platform, pushes vertically as high as possible, aiming for maximum height and elevation of the trunk (Parry et al., 2020). Given the similarity of the CMPU to the countermovement jump in terms of vertical force application, it is understood that it is possible to extract important performance variables related to the force-time curve (Parry et al., 2020). The CMPU applied to Australian Rugby League athletes demonstrated moderate to high reliability (ICC = 0.80-0.98 and 0.84-0.98) in the test-retest for rate of change of force, impulse and mean force of peak (Hogarth et al., 2013). In boxing athletes (Parry et al., 2021) the reliability of the CMPU was good to excellent (ICC > 0.77–0.98) for bilateral and unilateral evaluation of the right limbs (ICC > 0.67–0.93) and left (ICC > 0.79–0.98), confirming the reliable measurements extracted from the CMPU.

Despite the CMPU being a promising test, there are still few studies regarding its relationship with anthropometric variables. Contrasting this information, the Countermovement jump performance variables have already been compared to anthropometric variables, showing a negative correlation with body mass and fat percentage in volleyball athletes (Nikolaidis et al., 2017). Similarly, high levels of relationship have been established between the height and power of a Countermovement jump and total thigh muscle sectional area and other lower limb circumference measurements (Bahamondes-Avila et al., 2018). Considering this background and since the CMPU test demands the action of the upper limbs, it is necessary to analyze how the anthropometric variables of this region influence the power performance of this test. It is already possible to find many studies analyzing the CMPU test, however, studies that evaluate its efficiency in kickboxing athletes and the relationship of their performance variables with anthropometric data of the upper limbs are still scarce. Therefore, the aim of this study was to investigate the intra-test reliability of countermovement push-up measurements on the force platform in semi-professional kickboxing athletes and to analyze the association of variables with anthropometric measurements of the upper limb.

Material and Methods

Participants

The sample was chosen for convenience and the present study assessed 8 semi-professional kickboxing athletes, 7 male and 1 female athlete, with age = 20.4 (±3.8) years, body mass = 78.1 (±15.2) kg, and height = 1.74 (±0.07) m. All athletes from (7 national level and 1 international level) were recruited according to the following inclusion criteria: (1) having more than 5 years of kickboxing practice and 3 years in competition, (2) no history of neurological, cardiovascular, or orthopedic diseases in the last 6 months, (3) participation in official kickboxing competitions during the same year of the tests, (4) training at least 3 times per week, (5) being a minimum of 18 years old. The research was conducted following the ethical principles for medical research on human subjects of the Declaration of Helsinki (World Medical Association, 2013). Since the intervention was not invasive and posed no risk to participants, the study was not submitted for approval by an institutional ethics committee.

Procedures

The participants were assessed on the same day at 9 AM, the participants were instructed to not perform any physical activity for a period of 24 hours and to not eat for a period of 2 hours before the tests. First, the participants underwent an anamnesis to determine whether they met the inclusion criteria for the study. Once the requirements were met, an anthropometric measurement was performed, followed by a warm-up and the CMPU test. The data were acquired from kickboxing training centers in Rio de Janeiro. Data acquisition was performed in the final phase of the pre-competitive period for all athletes.

Anthropometric Assessment

The anthropometric measurements performed by an ISAK

(International Society for the Advancement in Kineanthropometry) level 2 certified professional. The following measurements were taken: body mass, height, triceps skinfold thickness (TF) and biceps skinfold thickness (BF), relaxed arm circumference (RAC), contracted arm circumference (CAC) and forearm circumference (FAC). Participants presented without strenuous exercise in the last 24 hours, after bladder emptying and wearing underwear. Three measurements were recorded for each variable, using the average of these.

Countermovement push-up

The evaluation was carried out using two previously validated PASCO PS-2141 monoaxial force plates (Sands et al., 2020). Before the evaluation, a warm-up was carried out in three blocks; general block, which consisted of performing joint mobility exercises and dynamic ballistic stretching for ten minutes, emphasizing the upper limbs; specific block where 3 middle zone exercises, front plank variants, and 2 push-up exercises of 3 series of 3 repetitions were used, where the width of the hands and the execution time varied; and a final block where the Countermovement Push-Up test was carried out in 2 series of 2 repetitions. The test was performed in a gymnasium on a rigid surface.

Participants were positioned supporting one hand on each platform, distributing their weight equally between them, with shoulders flexed at 90º, keeping elbows, trunk and lower limbs extended and malleoli together. The athletes were instructed to get off and on as quickly as possible and try to get off the platform as much as possible. Each subject made 3 attempts separated by 30 seconds of rest. The signals were registered through the PASCO CAPSTONE software with a sampling frequency of 1000 Hz.

Data Processing

The signals were processed by programs written in MATLAB (MathWorks, Natick, MA). The force platform signal was processed by a second-order low-pass Butterworth digital filter with a cutoff frequency of 50 Hz, he filters were applied in direct and reverse directions to avoid phase distortions. The CMPU variables were calculated: Push up height through flight time, Peak velocity, Peak force, Peak power, Rate of force development (RFD) yielding, RFD braking, Braking impulse and Concentric impulse.

Statistical analysis

The distribution of the data was analyzed using the Shapiro Wilk test. All data will be described through the median (M) and interquartile range (IQR). Absolute reliability was analyzed through the coefficient of variation expressed as percentage per subject, and the mean was calculated, considering acceptable values <10% (Atkinson & Nevill, 1998) and relative reliability through the intraclass correlation coefficient (ICC) with a two-factor mixed model of single measured form absolute agreement type (Trevethan, 2017), using the following thresholds for qualitative categorization: <0. 49 poor; 0.5 to 0.74 moderate; 0.75 to 0.89 good and >0.9 excellent (Koo & Li, 2016) presenting their 95% confidence intervals (CI). To determine the relationship between the physical test and anthropometric variables Spearman correlation coefficient test (r) was performed. Correlations were classified as: 0.0 to 0.10 trivial; 0.11 to 0.39 weak; 0.40 to 0.69 moderate; 0.70 to 0.89 strong and 0.90 to 1.00 very strong (Schober & Schwarte, 2018). All analyses will be performed in SPSS version 25 software with an alpha of 0.05.

Results

The descriptive statistics of the CMPU and anthropometric variables can be seen in Table 1. Table 2 shows the absolute and relative reliability of the variables. ICC and within-subject coefficient of variation calculations indicated that the performance measures had Poor to excellent reliability (ICC = 0.65–0.77, CV% = 5.6–20.8). Just ICC and within-subject coefficient of variation of Push-off time had Unclear reliability (ICC = 0.15–0.31, CV% = 7.5–14.9) and for RFD braking variables had poor to good reliability (ICC = 0.44, CV% = 27.4).

Table 1.
Descriptive statistics of CMPU and anthropometric variables

CMPU Variables	Md	Q1	Q3	Anthropometric	Md	Q1	Q3
Push-off height (m)	0.08	0.07	0.11	RAC (cm)	32.4	31.0	35.4
Peak velocity (m/s)	1.99	1.80	2.23	CAC (cm)	34.3	33.2	36.9
Push-off time (s)	1.04	0.99	1.06	FAC (cm)	27.7	27.1	29.7
Push-off distance (m)	0.64	0.55	0.74	TF (mm)	12.3	11.8	12.6
Braking impulse (N*s)	121	92	129	BF (mm)	3.75	3.5	4.5
Concentric impulse (N*s)	287	267	376				
CMPU Absolute	**Md**	**Q1**	**Q3**	**Normalized**	**Md**	**Q1**	**Q3**
Peak force (N)	992	877	1103	Peak force (N/kg)	19.1	17.6	21.75
Peak power (W)	1356	1119	1422	Peak power (W/kg)	24.8	21.8	29.09
RFD yielding (N/s)	1552	1018	2004	RFD yielding (N/s/kg)	26.5	21.4	40.25
RFD braking (N/s)	3067	2345	3986	RFD braking (N/s/kg)	59.2	48.3	75.00

Q1 interquartile 1; Q3 interquartile 1; RFD rate of force development; RAC relaxed arm circumference; CAC contracted arm circumference; FAC forearm circumference; TF tricipital fold; bicipital fold.

Table 2.
Absolute and relative reliability of CM push-off variables

Variables	CV (%)	ICC	IL 95%	UL 95%	Categorization
Push-off height	20.8	0.64	0.25	0.90	Poor to excellent
Peak velocity	7.1	0.74	0.38	0.93	Poor to excellent
Push-off time	7.5	0.14*	-0.23	0.67	Unclear
Push-off distance	11.1	0.70	0.32	0.92	Poor to excellent
Peak force	5.6	0.70	0.33	0.92	Poor to excellent
Peak power	8.6	0.77	0.43	0.94	Poor to excellent
RFD yielding	21.6	0.70	0.25	0.92	Poor to excellent
RFD braking	27.4	0.44	0.00	0.82	Poor to good
Braking impulse	16.0	0.73	0.36	0.93	Poor to excellent
Concentric impulse	7.6	0.76	0.41	0.94	Poor to excellent

* $p<0.05$; CM countermovement; RFD rate of force development; CV coefficient of variation; ICC intraclass correlation coefficients; IL inferior limit; UL upper limit.

Tables 3 and 4 show the Spearman correlation coefficient between the CMPU variables with the anthropometric variables. Significant with strong correlations were only found with the absolute variables of the CMPU. Strong to very strong correlations were found between RAC, CAC, FAC and BF with Concentric Impulse, Peak Force and Peak Power. In figure 4 are dispersion graph between CMPU variables and anthropometry.

Table 3.
Correlations between anthropometry and absolute CMPU variables

Variables		RAC	CAC	FAC	TF	BF
Jump height	rs	-0.42	-0.36	-0.36	0.05	-0.52
	p	0.30	0.39	0.39	0.91	0.18
Peak velocity	rs	0.13	0.17	0.17	-0.16	0.24
	p	0.76	0.69	0.69	0.71	0.56
Jump time	rs	0.55	0.52	0.52	0.54	0.28
	p	0.16	0.18	0.18	0.17	0.50
Push-off distance	rs	0.42	0.40	0.40	0.23	0.45
	p	0.30	0.32	0.32	0.59	0.27
Peak force	**rs**	**0.90**	**0.93**	**0.93**	-0.19	**0.78**
	p	**<0.01**	**<0.01**	**<0.01**	0.65	**0.02**
Peak power	**rs**	**0.78**	**0.79**	**0.79**	-0.42	**0.78**
	p	**0.02**	**0.02**	**0.02**	0.30	**0.02**
RFD yielding	rs	0.68	0.52	0.52	0.11	0.68
	p	0.06	0.18	0.18	0.80	0.07
RFD braking	rs	0.23	0.24	0.24	-0.04	0.19
	p	0.59	0.57	0.57	0.93	0.65
Braking impulse	**rs**	**0.85**	**0.91**	**0.91**	-0.05	0.65
	p	**<0.01**	**<0.01**	**<0.01**	0.91	0.08
Concentric impulse	**rs**	**0.95**	**0.91**	**0.91**	0.18	**0.75**
	p	**<0.01**	**<0.01**	**<0.01**	0.67	**0.03**

Bold values mean p <0.05; CMPU countermovement push-off; rs correlation coefficient of Spearman; RFD rate of force development; RAC relaxed arm circumference; CAC contracted arm circumference; FAC forearm circumference; TF tricipital fold; BF bicipital fold.

Table 4.
Correlations between anthropometry and relative CMPU variables

Variables		RAC	CAC	FAC	TF	BF
Peak force	rs	0.02	0.14	0.14	-0.28	0.03
	p	0.96	0.74	0.74	0.51	0.95
Peak power	rs	0.11	0.14	0.14	-0.19	0.17
	p	0.80	0.74	0.74	0.65	0.69
RFD yielding	rs	0.42	0.29	0.29	0.12	0.47
	p	0.30	0.49	0.49	0.78	0.24
RFD braking	rs	-0.08	0.00	0.00	-0.25	-0.09
	p	0.84	1.00	1.00	0.55	0.83

rs correlation coeficient of Spearman; RFD rate of force development; RAC relaxed arm circumference; CAC contracted arm circumference; FAC forearm circumference; TF tricipital fold; BF bicipital fold.

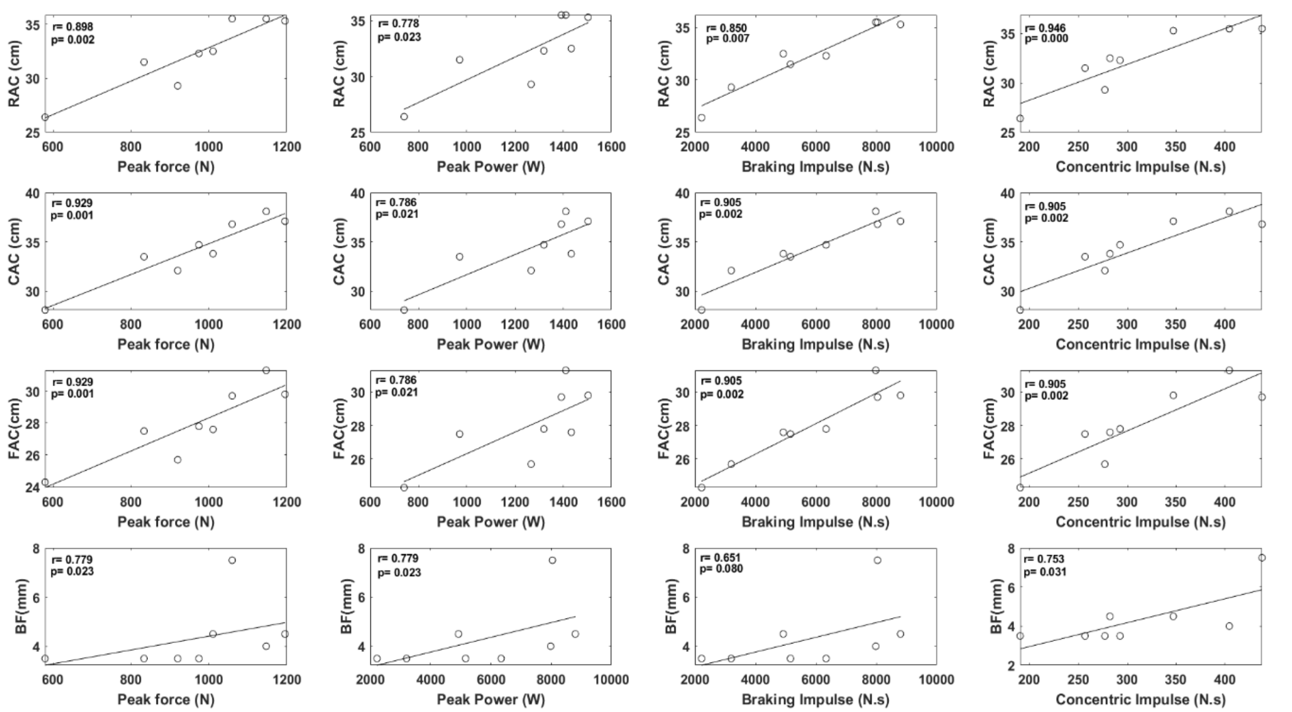

Figure 1. Dispersion graph between countermovement push-off variables and anthropometry.

Discussion

The aim of this study was to investigate the intra-test reliability of CMPU measurements on the force platform in semi-professional kickboxing athletes and to analyze the association of variables with anthropometric measurements of the upper limb. The majority of the CMPU variables exhibited an ICC ranging from 0.65 to 0.77, indicating moderate to substantial agreement among the participants. Additionally, the inter-subject coefficient of variation (CV%) ranged from 5.6% to 20.8%, suggesting a relatively low to moderate degree of variability between subjects. Furthermore, significant and strong correlations were found between the absolute variables of the CMPU and peak force and peak power. Specifically, strong to very strong correlations were observed between RAC, CAC, FAC and BF with both concentric impulse, peak force and peak power. These findings indicate that the majority of CMPU measurements on a force platform are reliable and consistent within this group of semi-professional kickboxing athletes. Moreover, the significant associations between upper limb anthropometric measurements and physical performance highlight the importance of these factors in kickboxing performance.

In the CMPU test the variables Peak Velocity, Peak Force, Peak Power and Concentric Impulse exhibited a CV% within acceptable (<10%) ranges, falling between 5.6% and 8.6%. Moreover, the ICC revealed consistent and reliable results, with moderate to good ICC values ranging from 0.702 to 0.761. The results obtained for Peak Force and Concentric Impulse align with previous studies that tested the ICC and CV% of the CMPU test in elite boxing athletes (Peak Force, ICC = 0.929, CV% = 4%; Concentric Impulse, ICC = 0.94, CV% = 8%) (Parry et al., 2021) and sub-elite rugby athletes (Peak Force, ICC = 0.8, CV% = 7.6%; Concentric Impulse, ICC = 0.85, CV% = 4.3%) (Hogarth et al., 2013). Furthermore, the values for Peak Power and Peak Velocity align with the results of a reliability study of CMPU in physically active individuals (Wang et al., 2017) with ICC values of 0.936 and 0.863, respectively. These consistent findings across different athletic populations highlight the robustness and reliability of these variables in evaluating kickboxing athletes' performance. The use of these variables in assessing kickboxing athletes can contribute to more effective training programs, injury prevention, and overall performance enhancement in this sport.

However, when examining other variables, such as Push-Up Height, Push-Off Distance, RFD Yielding, and Braking Impulse, it becomes evident that there were challenges in achieving consistent measurements. These variables exhibited a CV% ranging from 11.1% to 21.6%, which falls outside the commonly accepted range for reliability assessment. Despite this variability, it's worth noting that the ICC analysis still demonstrated moderate to good reliability, with ICC values ranging from 0.647 to 0.732. Sensitivity to the Push-Up Height variable in male youth rugby union players (Roe et al., 2016) for CV% was considered poor, corroborating with the results of this study. The reliability results for the RFD Yielding variable were consistent with those found in sub-elite male rugby league players (Hogarth et al., 2013) and male college athletes (Parry et al., 2019), where values above the acceptable range (>10%) for CV% and moderate to good ICC results were identified. Additionally, the ICC and CV% result for Braking Impulse was like the results (ICC = 0.79, CV% = 57.56%) found in physically active youth who performed the CMPU test with knee and hand support, indicating a CV% above the acceptable 10% and a good ICC rating (Bohannon et al., 2020). Greater familiarity with the experimental protocol, such as increased control of the lumbopelvic region, could possibly lead to more consistent CV% results for the CMPU test. While these results suggest a degree of inconsistency in these variables, their utility in assessing specific aspects of performance should not be dismissed entirely. Further investigations and refinements may help address the observed variability.

Push-off height and RFD Braking displayed an ICC with poor outcomes, ranging from 0.148 to 0.442. These findings indicate a significant degree of variability and inconsistency in the measurements of these variables, raising questions about their reliability for assessing aspects of performance. Additionally, the CV% for Flight Time was within an acceptable range at 7.5%, suggesting relatively stable measurements. However, RFD Braking exhibited a higher coefficient of variation, ranging from 14.9% to 27.4%, which exceeds the typical thresholds for reliability assessment. The acceptable CV% result (<10%) for the Flight Time variable aligns with the study using the CMPU test in elite male rugby league players (Hogarth et al., 2013) with CV% = 6.9 and boxers (Parry et al., 2021) with CV% = 6.9, however, it is not compatible with the ICC results of the two studies (ICC= 0.96; ICC=0.76, respectively). The difference in these results compared to those of the present study can be explained by the difference in the athletes' level involved, with elite athletes demonstrating improved reliability for tests compared to semi-professional athletes. As such, careful consideration is needed when utilizing these variables in assessing specific performance characteristics.

Both RAC and CAC demonstrated strong to very strong associations with concentric impulse, peak force, and peak power variables during the CMPU test, this agrees with previous research by Akagi et al. (2009), which found a positive correlation between the cross-sectional area of the biceps brachii and brachialis muscles and elbow flexion torque in both young and elderly males and females. Consequently, a greater arm circumference may signify a larger cross-sectional muscle area, potentially indicating higher power and strength in these segments. As for FAC, it also showed strongs and very strongs associations with kinetics variables, which is consistent with the findings of Joris et al. (1985), who found a positive correlation between forearm circumference and overhead ball throwing velocity in handball athletes. This association may be due to the ballistic nature of the CMPU similar to that of a bench press throw, in which wrist flexion and pronation are performed at the end of the concentric phase before take-off, contributing to push performance (Sakamoto et al., 2018). In contrast to the above, the correlations found between the kinetic variables and BF should be interpreted with caution. The visual scan Figure 1 identifies a possible outlier, corresponding to the maximum value of the sample (7.5 mm for BF). This may be due to not having been able to divide the analyses by weight category, due to the number of participants recruited. This value could have positively influenced the magnitude of the relationship found, and it is interesting to note that the p-values found oscillate between 0.02 and 0.03, unlike the other anthropometric variables, which in their great majority have a $p<0.01$. Therefore, a larger sample size is required to elucidate the associations found in this study. These findings suggest the influential role of upper extremity anthropometric characteristics in shaping CMPU test results.

A limitation of this study was the sample size, limiting the generalizability of the results to the population. In addition, due to the size of the sample, it was not possible to split the analyses according to kickboxing weight categories or gender of the participants, which could improve the understanding of CMPU performance by considering the characteristics of each fighter classification. Another limitation was not being able to directly measure the cross-sectional area of the main propulsive muscles involved in the CMPU, which could robust the results obtained. Future research is recommended to analyze the intra-test and test-retest reliability of the CMPU with a larger sample size that allows the analyses to be divided by weight category and sex. As well as to analyze the association of the CMPU variables with the cross-sectional area of the propulsive musculature involved in the test.

Conclusion

The results of this study underscore the reliability of CMPU testing in semi-professional kickboxing athletes using kinetic parameters extracted from the force platform for load control. This information is valuable for monitoring super compensation responses to training and tracking upper limb injuries, as the CMPU test can be effectively employed for enhanced injury evaluation and rehabilitation guidance until the athlete returns to peak performance levels. Additionally, the strong correlations suggest that variations in upper limb circumference may play a significant role in force and power generation during the concentric phase of the CMPU in kickboxers. Consequently, these findings emphasize the necessity of considering these anthropometric factors when devising tailored training regimens and assessments for individuals engaged in activities that heavily rely on upper body strength and power, such as kickboxing.

Acknowledge

Thanks to the DICYT Project, Code 022304AM_Ayudante, Vice-Rectorate for Research, Development and Innovation.

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Datos de los/as autores/as y traductor/a:

Pablo Merino-Muñoz	pablo.merino@usach.cl	Autor/a
Felipe Guimarães Teixeira	fegute1@hotmail.com	Autor/a
Jorge Pérez-Contreras	joperezc@gmail.com	Autor/a
Felipe Inostroza-Rios	felipe.inostroza.311@gmail.com	Autor/a
Aleksandro Ferreira	aleksandrofg@gmail.com	Autor/a
Ciro Brito	ciro.brito@usach.cl	Autor/a
Bianca Miarka	miarkasport@hotmail.com	Autor/a
Esteban Aedo-Muñoz	esteban.aedo@usach.cl	Autor/a
María de los Ángeles Rojas Suazo	mrojassuazo@gmail.com	Traductor/a