RBCDH Revista Brasileira de CINEANTROPOMETRIA e Desempenho Humano

DOI: http://dx.doi.org/10.5007/1980-0037.2015v17n5p507

original article

# Reliability of isometric and isokinetic peak torque of elbow flexors and elbow extensors muscles in trained swimmers

## *Reprodutibilidade do pico de torque isométrico e isocinético dos músculos flexores e extensores de cotovelo em nadadores treinados*

Natália Menezes Bassan[1]
Luiza Bertelli Simões[1]
Thadeu Elias Augusto Siqueira Cesar[1]
Renato Aparecido Corrêa Caritá[1]
Leonardo Coelho Rabelo de Lima[1]
Benedito Sérgio Denadai[1]
Camila Coelho Greco[1]

**Abstract** – In this study, it was hypothesized that the peak torque reliability would depend on the type of muscular action. The aim of this study was to analyze and to compare the reliability of isometric peak torque (IPT) and isokinetic peak torque at speeds of 60º.s$^{-1}$ and 180°.s$^{-1}$ (CPT60 and CPT180, respectively) of elbow flexors (EF) and elbow extensors (EE) muscles in trained swimmers. Twenty trained male swimmers (23 ± 5 years) performed the following protocols in different days: 1) Familiarization to isokinetic dynamometer; 2) Two maximal isometric voluntary contractions to determine IPT and five maximal concentric isokinetic contractions at 60º.s$^{-1}$ and 180°.s$^{-1}$ to determine CPT60 and CPT180, respectively (T1). The tests for IPT, CPT60 and CPT180 determination were performed in random order, and; 3) The same tests were performed in the same order of those performed on the second day (T2). There was no significant difference of IPT, CPT60 and CPT180 values between T1 and T2. Higher intraclass correlation coefficient (ICC) and lower typical error (TE) of IPT (ICC - 0.87 – 0.92; TE - 6.9 – 10.9%) in relation to CPT60 (CCI - 0.66 – 0.79, TE - 12.0 – 12.8%) and CPT180 (ICC - 0.85 - 0.85; TE - 8.5 – 9.2%) was observed. Based on these results, it could be concluded that the peak torque of EF and EE muscles presents moderate to excellent reliability, and can be influenced by the type of muscular action performed by trained swimmers.

**Key words**: Muscle fatigue; Skeletal muscle; Swimming; Resistance training.

**Resumo** – *Neste estudo, hipotetizou-se que a reprodutibilidade do pico de torque poderia depender do tipo de ação muscular. O objetivo do presente estudo foi analisar e comparar a reprodutibilidade do pico de torque isométrico (PTI) e do pico de torque isocinético concêntrico nas velocidades de 60º.s$^{-1}$ e 180°.s$^{-1}$ (CPT60 e CPT180, respectivamente) dos músculos flexores (FC) e extensores do cotovelo (EC) em nadadores treinados. Vinte nadadores treinados do gênero masculino (23 ± 5 anos) realizaram os seguintes protocolos, em diferentes dias: 1) Familiarização ao dinamômetro isocinético; 2) Duas contrações isométricas máximas para a determinação do PTI e cinco contrações isocinéticas máximas concêntricas a 60º.s$^{-1}$ e 180°.s$^{-1}$ para a determinação do CPT60 e CPT180, respectivamente (T1). Os testes para a determinação do PTI, CPT60 e CPT180 foram realizados de forma aleatória e; 3) Foram realizados os mesmos testes e na mesma ordem dos realizados no segundo dia (T2). Não houve diferença significante dos valores de PTI, CPT60 e CPT180 entre T1 e T2. Foi observado maior coeficiente de correlação intraclasse (CCI) e menor erro típico (ET) do PTI (CCI - 0,87 – 0,92; ET - 6,9 – 10,9%) em relação ao CPT60 (CCI - 0,66 – 0,79, ET - 12,0 – 12,8%) e CPT180 (CCI - 0,85- 0,85; ET - 8,5 – 9,2%). Com base nestes resultados, é possível concluir que o pico de torque dos músculos FC e EC apresenta reprodutibilidade entre moderada e excelente, podendo ser influenciada pelo tipo de ação muscular realizada em indivíduos treinados na natação.*

**Palavras-chave**: *Fadiga muscular; Músculo esquelético; Natação; Treinamento de Resistência.*

1 São Paulo State University. Human Performance Laboratory. Rio Claro, SP. Brazil

Received: 30 March 2015
Accepted: 20 May 2015

## INTRODUCTION

The use of isokinetic dynamometer has helped in understanding the neuromuscular response to exercise, since it is carried out under well-controlled conditions (speed, body position) and can thus be used for different purposes (sports and clinical)[1]. This dynamometer allows the muscle torque to be measured in the different joints in an isometric (with different joint angles), concentric and eccentric forms (at different speeds)[2,3]. The main advantage of using the isokinetic dynamometer is to maintain angular speed constant over most of the movement range, allowing greater precision and possibly greater measurement reproducibility[4]. In the sports environment, isokinetic dynamometry has been used for neuromuscular assessment of athletes aimed at training control[5], identification of muscle imbalance[6] and to assist in the recovery of muscle injuries[1].

In swimming, muscle strength is an important aspect for the assessment and training of athletes[7]. In front crawl swimming, elbow flexors (EF) and elbow extensors (EE)[8] are among the major muscle groups used in the stroke due to their importance in stabilizing the joint and transmission of hand and forearm strength to the body displacement[9]. In addition, the forces of biceps and triceps muscles decrease the momentum at the end of the recovery phase to replace the contralateral arm in the next stroke[10]. In fact, studies analyzing muscle activity during crawl swimming[11-13] verified reduction in integrated electromyographic activity (iEMG) of biceps and triceps muscles in maximum short-distance tests (100-200 m)[11-13], suggesting the occurrence of muscle fatigue (i.e., decreased strength) under these conditions. Therefore, accurate and reliable neuromuscular assessment of these muscles in swimmers may be important for the control of performance and identification of muscle fatigue. It is noteworthy that different muscle actions (isometric and isokinetic, respectively) have been used for these purposes[5,14]. However, Hopkins et al.[15] have suggested that reproducibility can be speed-dependent used in neuromuscular assessments, and may show greater variability in measurements with increasing speed. These authors also suggest that trained individuals have higher reproducibility in different physical fitness tests. To our knowledge, there are no studies that have investigated the reproducibility of the peak torque of EF and EE muscles in different muscular actions and angular velocities of trained swimmers.

Thus, the aim of this study was to analyze and compare the reproducibility of isometric peak torque (IPT) and concentric isokinetic peak torque at speeds of 60°.s$^{-1}$ and 180°.s$^{-1}$ (CPT60 and CPT180, respectively) of EF and EE muscles in trained swimmers. Based on observations of Hopkins et al.[15], it was hypothesized that the peak torque reproducibility might depend on the type of muscle action, i.e., the isometric contraction would present greater reproducibility with respect to concentric isokinetic contractions performed at 60°.s$^{-1}$ and 180°.s$^{-1}$. Angular velocities 60°.s$^{-1}$ and 180°.s$^{-1}$ were adopted due to their resemblance to the speed of swimmers movements[5,16].

The analysis of the reproducibility of peak torque measures in different muscle actions can contribute to the evaluation of athletes under different conditions such as in the analysis of muscle fatigue, and also for the control of muscle strength during longitudinal monitoring of the training effects.

## METHODOLOGICAL PROCEDURES

### Subjects

The study included 20 male swimmers (age: 23 ± 5 years; height: 177.3 ± 6.3 cm; body mass: 74.4 ± 8.4 kg), regular competitors of regional and national swimming events. All had at least five years of experience in the sport, completing 12 weekly hours of training in the study phase, no smokers and no regular use of any medication. Swimmers were informed about the experimental procedures and their implications, signing the informed consent form. The project was approved by the Ethics Committee of the Institution and was conducted in accordance with the Declaration of Helsinki on the use of human beings as research participants (Protocol 128/13).

### Procedures for data collection

Athletes performed the following experimental procedures on different days: 1) On the first visit, anthropometric measurements were obtained and athletes were familiarized with the isokinetic dynamometer (System 3, Biodex Systems, USA). During familiarization, athletes performed two isometric contractions and 5 concentric contractions at speeds of 60°.s$^{-1}$ and 180°.s$^{-1}$ for each of the muscle groups (EF and EE); 2) Tests for determining IPT, CPT60 and CPT180 of EF and EE muscles in isokinetic dynamometer (T1), and; 3) The same tests were performed in the same order for each athlete (T2). Tests were performed for the dominant limb, and the execution order (i.e., IPT, CPT60 or CPT180) was randomized for each athlete. A 3-min interval between each test was observed. The volunteers were instructed not to train intensively on the day before the trial and to attend on the test day fed and hydrated. All tests were performed on the same time of day at laboratory with controlled temperature (21 -23 ° C). There was an interval of 48-72 hours between session 1 and 2. There was an interval of 48 hours between experimental sessions 2 and 3. This range was used because it is close to the interval (2.5 days) in which the coefficient of variation tends to be lower[15].

### Torque assessment

To determine IPT, CPT60 and CPT180, athletes were positioned seated on the isokinetic dynamometer. Each volunteer was stabilized on the chair with two belts crossed at 30°, fastened from the shoulder and fixed to the opposite side of the waist. The individual remained in contact with the chair throughout the test to prevent trunk movement (Figure 1). To measure IPT, the angles adopted were based on previous studies[5,16]. For EF muscles, subjects remained seated with elbow leaning on a cushion with forearm

flexion of 90° and in supine position (Figure 1). For the EE muscles, the position was similar, except for the initial forearm positioning in pronation[5].

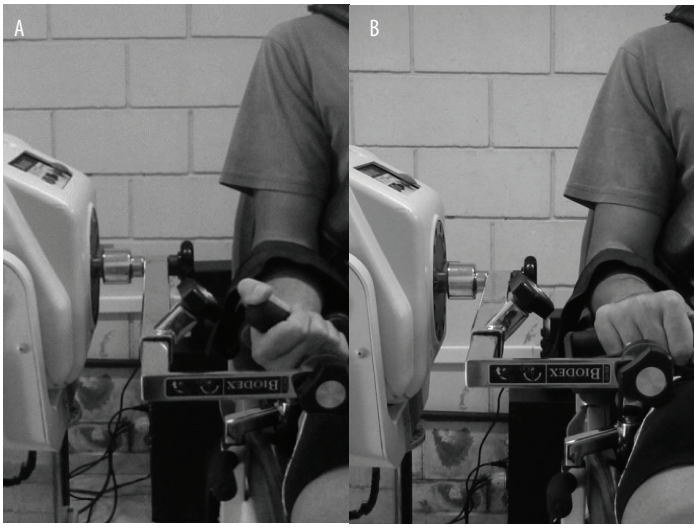


**Figure 1.** Volunteer's positions on the dynamometer during isometric testing for elbow flexors (A) and extensors muscles (B).

For the IPT evaluation, two maximal voluntary isometric contractions were performed, each of which was maintained for a period of 3 s, with rest of three minutes between each. The instruction given to the volunteers was to start the contraction as fast and strong as possible, keeping the effort until the end of 3 s. Contraction with the highest peak torque was used for analysis of IPT.

CPT60 and CPT180 were evaluated in a similar manner to that described for isometric contraction. However, for isokinetic contractions of EE muscles, the initial position was regarded as the point at which the elbow was flexed at 90° and in the final at 180° (total extension) with motion range of 90°[17] (Figure 2). For EF muscles, only the forearm position was changed to the supine position. In this case, the initial position adopted was the point in which the arm was in full extension, and the final position with elbow flexed at 110°[18] (Figure 3).

Finally, to determine CPT60 and CPT180, five maximal concentric isokinetic contractions were performed. This procedure was performed at speeds of $60^{o}.s^{-1}$ and $180^{o}.s^{-1}$. For these variables, the highest value reached in contractions in each of speeds was considered.

Torque data were obtained at frequency of 1000 Hz by a signal acquisition module (EMG System®) synchronized with the isokinetic dynamometer. Data were filtered by a $4^{th}$ order Butterworth low pass digital filter with cut-off frequency of 15 Hz and analyzed using the MatLab 6.5 software (Mathworks, USA). Peak torque was considered the greatest value achieved in one of two contractions.

## Statistical analysis

Values are expressed as mean ± SD. Normality was verified by the Shapiro-

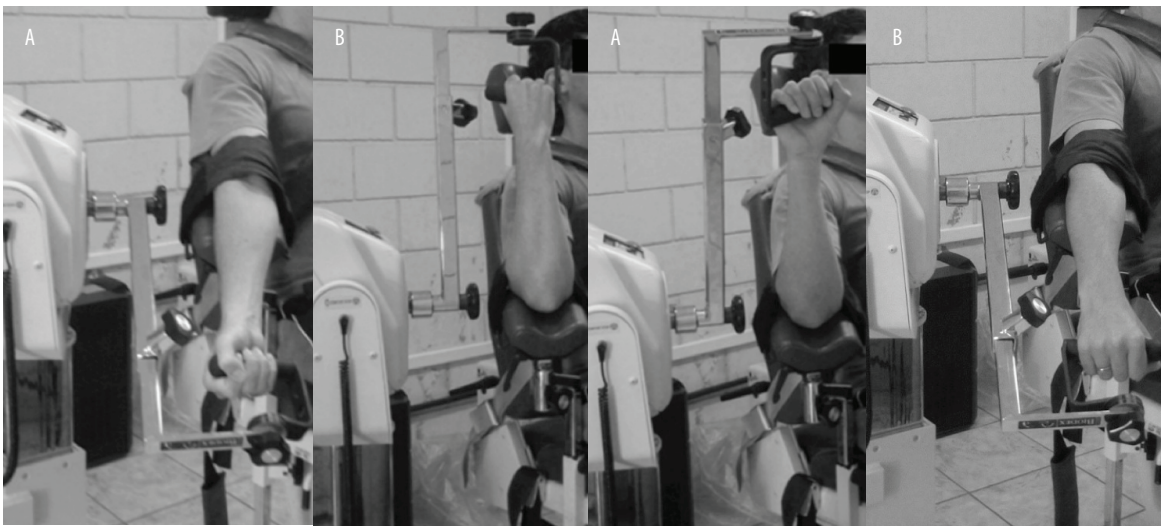


**Figure 2.** Initial (A) and final (B) positions of volunteer in the dynamometer during isokinetic test for elbow flexor (upper panel) and elbow extensors muscles (lower panel). Elbow flexors – Initial movement in full extension (180) and final movement at 110° of flexion with forearm in supine position. Elbow extensors - Initial movement in elbow flexion at 90° and final movement in full extension (180°), with pronated forearm.

Wilk test. To compare the peak torque values between T1 and T2, the Student *t* test was used, with significance level kept at $p < 0.05$. Intraclass correlation coefficient (ICC), typical error (TE) and confidence interval (95%) of measures were calculated. Reliability was classified according to the ICC values as poor (<0.40), moderate (0.40 to 0.75) and excellent (> 0.75)[19].

## RESULTS

The mean values ± SD of IPT, CPT60 and CPT180 obtained in tests 1 (T1) and 2 (T2) for EF and EE muscles are shown in Table 1. No significant differences were observed in IPT, CPT60 and CPT180 of EF and EE muscles between T1 and T2 ($p > 0.05$).

**Table 1.** Mean values ± SD of isometric (IPT) and isokinetic peak torque at $60°.s^{-1}$ (CPT60) and $180°.s^{-1}$ (CPT180) obtained in test 1 (T1) and 2 (T2) for elbow flexor (EF) and extensor muscles (EE). N = 20

| | EF | | | EE | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | p | T1 | T2 | p |
| IPT (N.m) | 74.4 ± 18.9 | 73.4 ± 17.5 | 0.43 | 88.4 ± 24.7 | 81.5 ± 22.6 | 0.18 |
| CPT60 (N.m) | 50.9 ± 11.7 | 49.5 ± 13.9 | 0.36 | 67.5 ± 14.3 | 69.1 ± 16.8 | 0.37 |
| CPT180 (N.m) | 45.0 ± 10.3 | 44.7 ± 8.7 | 0.46 | 57.9 ± 10.9 | 58.2 ± 14.3 | 0.46 |

The IPT, CPT60 and CPT180 values of EF and EE muscles in T1 and T2 are shown in Figure 3. TE for IPT, CPT60 and CPT180 was 6.9%, 8.5% and 12% for EF and 10.9%, 12.8% and 9.2% for EE, respectively. Based on the ICC, it was found that IPT and CPT180 showed excellent reproducibility, while for CPT60, reproducibility was moderate to excellent (Figure 3).

ICC values and CI95% of IPT, CPT60 and CPT180 of EF and EE muscles in T1 and T2 are shown in Figure 4. IPT and CPT180 showed excellent reproducibility, while for CPT60, reproducibility was moderate to excellent.

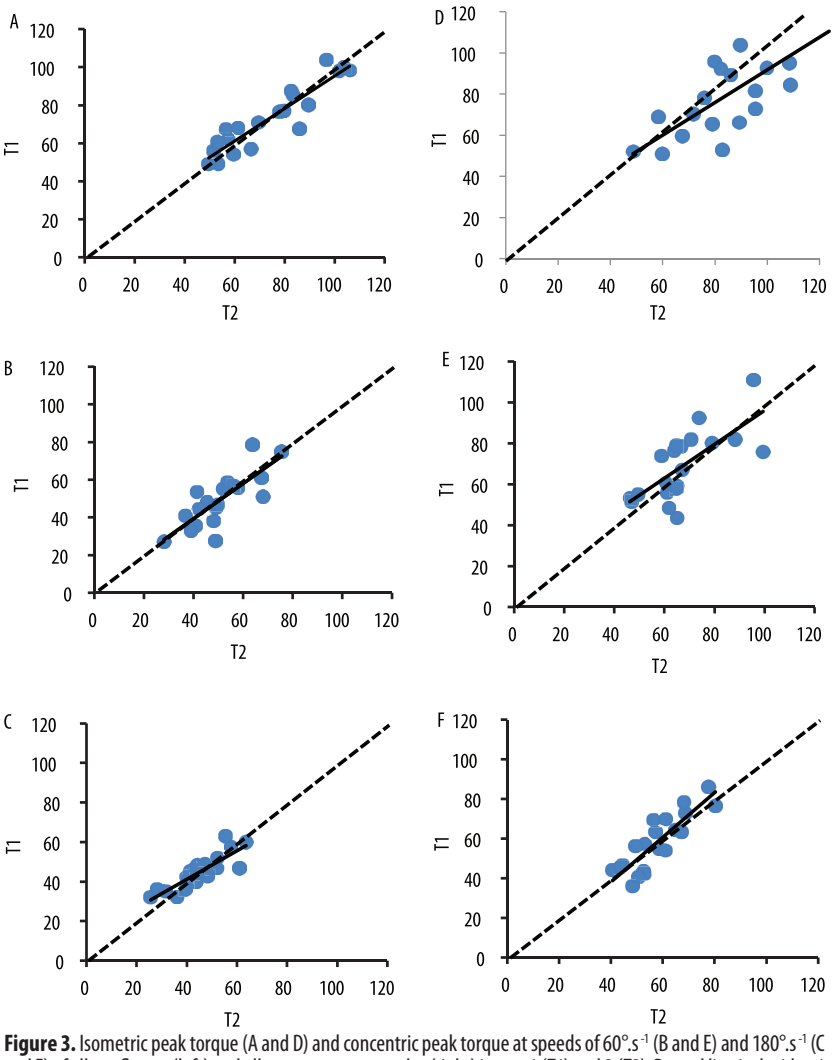


**Figure 3.** Isometric peak torque (A and D) and concentric peak torque at speeds of 60°.s$^{-1}$ (B and E) and 180°.s$^{-1}$ (C and F) of elbow flexors (left) and elbow extensors muscles (right) in test 1 (T1) and 2 (T2). Dotted line is the identity line. Solid line is the regression line. ICC - intraclass correlation coefficient; CI95% - confidence interval. N = 20.

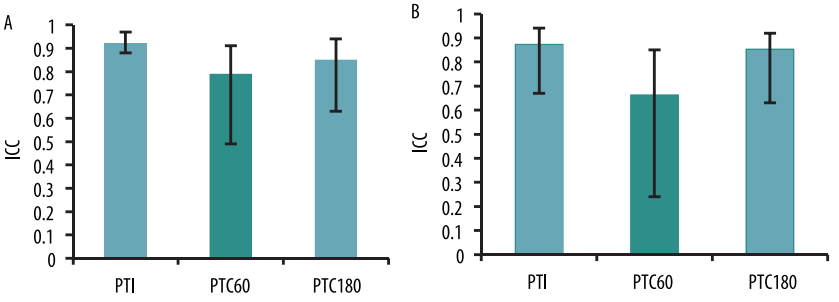


**Figure 4.** Intraclass correlation coefficient values and confidence interval of isometric (IPT) and isokinetic peak torque at 60°.s$^{-1}$ (PT60) and 180°.s$^{-1}$ (PT180) of elbow flexors (panel A), and elbow extensors muscles (panel B) in tests 1 and 2. N = 20

## DISCUSSION

The aim of this study was to analyze and compare the reproducibility of IPT, CPT60 and CPT180 of EF and EE muscles in trained swimmers. The main finding of this study was that IPT had higher reproducibility than that shown by CPT60 and CPT180. These data confirm our initial hypoth-

esis, showing that the PT reproducibility can be influenced by the type of muscle action performed by trained swimmers.

Strength tests using isoinertial and isokinetic contractions have been used to monitor the effects of training and rehabilitation, since they seem to have a greater relationship with functional changes obtained during these processes[20]. However, isometric tests have been widely used to identify muscle fatigue[21] and to determine the rate of force development, which is an important indicator of explosive muscular strength[22]. It is therefore essential to establish the reliability of peak torque measures (PT) in these different modes of muscle action in different populations.

When comparing isometric with dynamic contraction, it has been considered that the former reduces the influence of external variables such as joint stabilization and synergistic activity[23]. This allows complete voluntary activation, since this tends to recruit greater amount of motor units[24]. In addition, it is suggested that there are differences in the recruitment patterns of motor units during these different muscle actions[25]. In the present study, it was found that IPT had higher reproducibility than those found in isokinetic contractions. To our knowledge, there are no studies that have examined the reproducibility (ICC and TE) of IPT of EF and EE muscles. Anyway, our data regarding the PTC reproducibility seem to be similar to those found in non-trained individuals. Griffin[26] found similar reproducibility levels of EF at 30°.s$^{-1}$ (ICC = 0.83) and 120°.s $^{-1}$ (ICC = 0.82). In another study, Lund et al.[27] found ICC values of 0.97 and 0.93 for PTC at 60°.s$^{-1}$ of EF and EE, respectively. However, our data are apparently different from those found during tests performed on knee extensors during open kinetic chain exercises[4,28]. In these studies, it was found that the ICC values were similar during isometric (0.88 to 0.97) and concentric contractions carried out at 60°.s$^{-1}$ (0.89 to 0.97) and 180°.s$^{-1}$ (0.99). However, when the PT of knee extensors was evaluated during closed kinetic chain exercise, Callaghan et al.[29] found better reproducibility during isometric contraction (ICC = 0.82 to 0.86) than during isokinetic contraction at 60°.s $^{-1}$ (ICC = 0.55 to 0.76). These apparently antagonistic results may perhaps be explained by the different joints (knee vs. elbow) and / or type of exercise (open vs. closed kinetic chain) used. These factors probably influence the stability of body segments (open chain vs. closed chain) and in the fixation of the body segment in relation to the dynamometer (knee vs. elbow) and consequently in muscle activation and participation of synergist muscles, which may interfere with test and re-test values. In any case, previous comparisons must be carried out with caution, because in these studies, tests were performed with different time intervals between them. While in the study of Griffin[28], tests were performed on the same day, in other studies, the time interval was between 2 and 5 days[29] and one week[27]. Hopkins et al.[15] found that the variation coefficients may depend on the time interval between test and re-test, being smaller between 2 and 3 days. Shorter intervals between tests could be influenced by fatigue, and longer periods could lead to larger individual changes.

In practical terms, it is possible to use reproducibility of measurements (e.g., TE) to detect the smallest individual change necessary to point a change as real and therefore above the measurement error limits [30]. Using the limits (i.e., 1.5 to 2 x TE) proposed by Hopkins[30], changes above the range between 10 and 14% in the IPT of EF muscles would be needed so that an individual change could be considered real. In a recent study, Bassan et al.[14] found that the IPT of EF muscle was significantly decreased (~ 16%) after exhaustive swimming exercise (~ 220 s). Thus, the IPT of EF muscle has high chance to detect individual changes in muscle fatigue. For isokinetic contractions, the necessary changes found in this study should be above the range between 13 and 25%. Girold et al.[5] found an increase in the IPT of EF (60°.s$^{-1}$ = 16%, 180°.s$^{-1}$ = 6%) and EE muscles (60°.s$^{-1}$ = 33%, 180°.s$^{-1}$ = 35%) after 12 weeks of strength training in trained swimmers. Under these conditions, the IPT of EF and EE have respectively moderate and high chance to detect the effects of training in trained swimmers. Therefore, regardless of purpose (e.g., fatigue, training or rehabilitation), isometric tests appear to have a greater chance to identify individual changes with real physiological and / or functional significance.

Finally, a potential limitation in this study should be highlighted. Recently, Bassan et al.[14] found that muscle fatigue can decrease the reproducibility of the IPT of EF and EE muscles after maximal exercise in swimming (~ 220 s). So far, the effects of possible interactions between fatigue and the different muscle actions on the reproducibility of muscle torque measurements are not fully elucidated. Thus, future studies should examine the reproducibility of peak torque under these conditions (i.e., fatigue and different contraction speeds), as these data may assist in the use of neuromuscular assessment tests in athletes under different conditions (e.g., with and without fatigue).

## CONCLUSION

It can be concluded that the IPT of EF and EE muscles shows moderate to excellent reproducibility. IPT had higher ICC and lower TE than CPT60 and CPT180, suggesting that the PT reproducibility of EE and EF muscles can be influenced by the type of muscle action performed in trained swimmers. Familiarization and the positioning of the athlete on the dynamometer should be made carefully in order to increase data reliability, especially during isokinetic contractions.

## REFERENCES

1. Dvir Z. Isocinética: avaliações musculares, interpretações e aplicações clínicas. São Paulo: Manole; 2002.
2. Iossifidou AN, Baltzopoulos V. Inertial effects on the assessment of performance in isokinetic dynamometry. Int J Sports Med 1998;19:567-73.
3. Svensson M, Drust B. Testing soccer players. J. Sports Sci 2005;23:601-18.
4. Maffiuletti NA, Bizzini M, Desbrosses K, Babault N, Munzinger U. Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. Clin Physiol Func Imag 2007;27:346-53.

5. Girold S, Maurin D, Dugue B, Chatard JC, Millet G. Effects of dry-land vs. Resisted- and assisted-sprint exercises on swimming sprint performances. J Strength Cond Res 2007;21(2):599-605.
6. de Abreu Camarda SR, Denadai BS. Does muscle imbalance affect fatigue after soccer specific intermittent protocol? J Sci Med Sport 2012;15(4):355-60.
7. Maglischo EW. Nadando sempre mais rápido. São Paulo: Manole, 2010.
8. Rouard, AH, Clarys JP. Cocontraction in the elbow and shoulder muscles during rapid cyclic movements in an aquatic environment. J Electromyogr Kinesiol 1995; 5(3):177-83.
9. Madsen JE, Flugsrud G. Radial head fractures: indications and technique for primary arthroplasty Eur J Trauma Emerg Surg 2008;34(2):105-12.
10. Lauer J, Figueiredo P, Vilas-Boas JP, Fernandes RJ, Rouard AH. Phase-dependence of elbow muscle coactivation in front crawl swimming. J Electromyogr Kinesiol 2013;23(4):820-5.
11. Aujouannet YA, Bonifazi M, Hintzy F, Vuillerme N, Rouard AH. Effects of a high-intensity swim test on kinematic parameters in high-level athletes. Appl Physiol Nutr Metab 2006;31(2):150-8.
12. Stirn I, Jarm T, Kapus V, Strojnik V. Evaluation of muscle fatigue during 100-m front crawl. Eur J Appl Physiol 2011;111(1):101-13.
13. Ikuta Y, Matsuda Y, Yamada Y, Kida N, Oda S, Moritani T. Relationship between decreased swimming velocity and muscle activity during 200-m front crawl. Eur J Appl Physiol 2012;112(9):3417-29.
14. Bassan NM, Cesar TEAS, Denadai BS, Greco CC. Relationship between fatigue and changes in swim technique during an exhaustive swim exercise. Int J Sports Physiol Perform 2015 Apr 7. [Epub ahead of print]
15. Hopkins WG; Schabort, EJ; Hawley JA. Reliability of power in physical performance tests. Sports Med 2001;31(3):211-34.
16. Girold S, Jalab C, Bernard O, Carette P, Kemoun G, Dugué B. Dry-land strength training vs. electrical stimulation in sprint swimming performance. J Strength Cond Res 2012;26(2):497-505.
17. Jurimae J, Abernethy PJ, Blake K, Mceniery MT. Changes in the myosin heavy chain isoform profile of the triceps brachii muscle following 12 weeks of resistance training. Eur J Appl Physiol Occup Physiol 1996;74:287-92.
18. Gauthier A, Davenne D, Martin A, Van Hoecke J. Time of day effect on isometric and isokinetic torque developed during elbow flexion in humans. Eur J Appl Physiol 2001;84(3):249-52.
19. Fleiss JL, Levin B, Paik MC. Statistical methods for rates and proportions Hoboken, New Jersey: Wiley:2003.
20. Wilson GJ, Murphy AJ. The use of isometric tests of muscular function in athletic assessment. Sports Med 1996;22(1):19-37.
21. Greco CC, Silva WL, Camarda SR, Denadai BS. Fatigue and rapid hamstring/quadriceps force capacity in professional soccer players. Clin Physiol Funct Imaging 2013;33(1):18-23.
22. Molina R, Denadai BS. Dissociated time course recovery between rate of force development and peak torque after eccentric exercise. Clin Physiol Funct Imaging 2012;32(3):179-84.
23. Williams C, Ratel S. Human Muscle Fatigue. London: Routledge, 2009.
24. Newham DJ, Mccarthy T, Turner J. Voluntary activation of human quadriceps during and after isokinetic exercise. J Appl Physiol 1991;71(6):2122-6.
25. Komi PV, Tesch P. EMG frequency spectrum, muscle structure, and fatigue during dynamic contractions in man. Eur J Appl Physiol Occup Physiol 1979;42:41-50.
26. Griffin JW. Differences in elbow flexion torque measured concentrically, eccentrically, and isometrically. Phys Ther 1987;67:1205-8.
27. Lund H, Søndergaard K, Zachariassen T, Christensen R, Bülow P, Henriksen M et al. Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers. Clin Physiol Funct Imaging 2005;25(2):75-82.

28. Alvares JBAR, Rodrigues R, Franke RA, da Silva BG, Pinto RS, Vaz MA et al. Inter-machine reliability of the Biodex and Cybex isokinetic dynamometers for knee flexor/extensor isometric, concentric and eccentric tests. Phys Ther Sport 2015;16(1):59-65.
29. Callaghan MJ1, McCarthy CJ, Al-Omar A, Oldham JA. The reproducibility of multi-joint isokinetic and isometric assessments in a healthy and patient population. Clin Biomech 2000;15(9):678-683.
30. Hopkins WG. Measures of reliability in sport medicine science. Sport Med 2000;30(1):1-15.

**Corresponding author**

Camila Coelho Greco
Laboratório de Avaliação da Performance Humana, IB – UNESP.
Avenida 24 A, 1515, Bela Vista.
CEP 13506-900 - Rio Claro, SP. Brasil.
E-mail: grecocc@rc.unesp.br