Original Article

Maxforce: The new option in strength, health levels and life expectancy measurement

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ABSTRACT

One of the biggest challenges faced by western life-style countries is to stem the current major public health epidemic of cardiac-metabolic diseases that is creating an excessive financial and social burden. These mostly preventable diseases are triggered mainly by physical inactivity and unhealthy diets leading to an excess accumulation of bodyfat, increased inflammation and diminished strength and muscle mass. The aim of this study was to test the reliability and validity of the strength measurement by the new MaxForce interactive dynamometer and to emphasize the importance of using these devices within the sanitary system. 97 voluntary subjects joined the study using two different dynamometers for strength measurement. We note high interclass correlation rates in the MaxForce dynamometer validity and reliability measurements (0.997 and 0.986 respectively) and a measurement error under 1.72% in relation to 5.38% of the manual dynamometer. The results endorse the validity and reliability of the MaxForce device as valuable high precision tool for measuring strength, health levels, life expectancy and sports performance for the health care professionals. MaxForce, also facilitates the strength measurement and training of many different muscle groups, which added to the audiovisual feedback makes this device a practical and useful system to improve the adhesion and motivation for training. The implementation in the sanitary system could enhance general health levels and improve of treatment results of numerous pathologies. **Keywords:** Dynamometer; Validity; Reliability; Life-style.

Cite this article as:
Pérez-Turpin, J.A., Gomis-Gomis, M.J., Pérez-Suárez, P., & Suárez-Llorca, C. (2019). Maxforce: The new option in strength, health levels and life expectancy measurement. *Journal of Human Sport and Exercise*, *14*(4), 841-855. doi:https://doi.org/10.14198/jhse.2019.144.13

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Submitted for publication December 2018
Accepted for publication December 2018
Published December 2019 *(in press* January 2019)
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2019.144.13

INTRODUCTION

Hypertension is considered a global health crisis by the WHO, and is the main risk factor for death and disability in adults as well as being the most common chronic condition in primary health care. The implementation of therapies to reduce and maintain blood pressure is very important for public health (McGowan et al., 2017).

As documented by Stenholm et al. (2010), sarcopenia is a major public health problem in the elderly. Sarcopenia, low strength and muscle mass, is the main cause of disability and the main predisposing factor of functional limitations, higher risk of falls and mortality (Cruz-Jentoft et al., 2010; Fougère et al., 2015; Lauretani et al., 2003). According to the United Nations perspectives, it is expected that the number of people over the age of 60 will double by 2050, which will represent more than 35% of the European population, thus increasing the prevalence of diseases and the associated health expenditure (McLeod et al., 2016). This implies the search for strategies to maintain the function and capacity to live independently, placing the focus on skeletal muscle (Fougère et al., 2015).

Diseases such as obesity, hypertension, cardiovascular disorders, type 2 diabetes, some types of cancer, cognitive disfunction, autoimmune diseases, sarcopenia and osteoporosis are due to an imbalance between our physiology the diet and life-style and they happen to be chronic, degenerative and epidemic diseases (Carrera-Bastos et al., 2011). The consequence is an alarming increase in a social and economic burden that many experts warn might bankrupt national health care services.

It has been estimated that reducing 10% of the muscle mass loss related to age would save $1 billion a year in health care in the USA alone (Janssen et al., 2004). One of the main problems addressing this issue in the current health care system is the fact that general physical condition levels, muscle mass and strength receive very little medical care or attention.

The first step to provide a solution is to recognize and communicate how important the skeletal muscle mass is in the development, treatment and prevention of diseases. Additionally we must also find tools, strategies and protocols in order to improve people's life quality through the increase and improvement of muscle function and implement them in hospitals, geriatric centres and primary health care centres, etc.

It's well known that the skeletal muscle is the most abundant tissue in a healthy adult body, representing about 50% of the total body weight of a healthy adult (Janssen et al., 2004; Kalyani et al., 2014) and it decreases with age to approximately 25% or less between the 75 and 80 years old. Aging, inactivity and most chronic diseases accelerate the loss of muscle mass and strength increasing the risk of disability, hospitalization and premature death (Kalyani et al., 2014).

Apart from locomotion functions, body and energy stability, the muscle plays an important role in the homeostasis maintenance of the organism (Sakuma and Yamaguchi., 2012; Yang and Kuang., 2014), being the main determinant in the correct functioning of body metabolism (Ahima and Park., 2015; Pedersen and Febbraio, 2012; Yang and Kuang., 2014), of the total energy expenditure (Gil and de Medina, 2005; Pedersen and Febbraio, 2012) and the main factor for weight control and body composition (Yang and Kuang., 2014).

The muscle tissue plays a crucial role in the body metabolism, first by providing the essential amino acid to maintain the proteic synthesis and therefore the protection and regeneration of tissues and vital organs such as brain, heart, liver and skin (Biolo et al., 1995; Cahill, 1970; Felig et al., 1969; Wolfe, 2006), but also by contributing in the correct glucose and lipid metabolism (Jeukendrup et al., 1998a; Jeukendrup et al., 1998b; Pedersen, 2011; Pedersen and Febbraio, 2012).

The maintenance of muscle mass assures some basic functions such as breathing, digestion and blood circulation. On top of this, the skeletal muscle has been recently identified as a myosin secretory which links the muscles to other organs. This helps understand the mechanisms by which the metabolism is influenced by physical exercise and the anti-inflammatory and addaptative effects (Ahima and Park, 2015; Fiuza-Luces et al., 2013; Nimmo et al. ,2013; Pedersen, 2013; Pedersen and Febbraio, 2008; Yang and Kuang, 2014), in the stress and disease endurance (Anker and Coats, 1999; Anker and Sharma, 2002; Arnold et al. ,1993; Biolo et al., 2002; Keys et al., 1950; Sugden and Fuller, 1991) and in cognitive improvements (Fiuza-Luces et al., 2013; Van Praag, 2009). This has a big impact in general health since inflammation is a degenerative factor and a precursor of most chronic diseases. Also, the myosins released by the muscle prevent inflammation and insulin resistance (Walsh, 2009; Pedersen, 2010).

Some studies suggest that muscle strength could be more important than muscle mass as a determinant factor of functional limitations and the mobility state in older age (Newman et al., 2006; Visser et al., 2005). Therefore, keeping up muscular health should be one of the main focuses in pathology treatment and prevention. Strength is an indicator of functionality and muscular health and its evaluation is scientifically accepted as a precise forecast value to evaluate general health, discapacity, morbidity, mortality, general muscular strength and life expectancy.

It is essential for health care professionals, to have access to useful and affordable tools for the evaluation, prescription, registration and tracking of strength training as both a treatment and prevention method.

In health-related science, the different dynamometers that measure the gripping force represent a tool related to measuring life quality (Sayer et al., 2006), different pathologies and mortality for any cause. (Strand et al., 2016) In Sports science the value of strength and isometric training have been traditionally used to prevent and treat sport injuries, talent detection and general performance improvement in sports. (Cronin et al., 2017).

From the standpoint of health care, the gripping force is an accurate consistent predictor of health levels among middle and older age people (Sasaki et al., 2007), emerging as a stronger cardiovascular mortality predictor than blood pressure (Leong et al., 2015), as a clinical marker to predict the risk of mortality due to any relevant cause other than systolic pressure or obesity (Firth et al., 2018) and as a biomarker of aging and low mobility (Strand et al., 2016). Therefore, strength should be a crucial evaluating factor in various domains for the general population's health due to its predictive factor of a weak muscle mass (Leong et al., 2015).

In practical geriatrics, low gripping force identifies a risk of rapid deterioration, sarcopenia sieving, dependence in everyday activities, discapacity, cognitive deterioration and mortality; in terms of lower functional, psychological and social health levels. (Lauretani et al., 2003; Strand et al., 2016; Taekema et al., 2010).

In adults, a weaker gripping force is associated with a decrease in life quality (Sayer et al., 2006) and can be used to identify a higher risk of mobility limitation, future discapacity, fallings, morbidity and mortality for all the previous causes (Leong et al., 2015; Sasaki et al., 2007; Strand et al., 2016). Besides, gripping force is positively and significantly related to the cognitive capacities such as visual memory, reaction time, reasoning, digital memory and prospective memory, being usable in detecting risks of developing a general cognitive deterioration according to age (Firth et al., 2018).

In adolescents, a weak gripping force is considered an emerging risk of the main death causes in early adulthood such as cardiovascular diseases (Ortega et al., 2012) and it's associated with a higher risk of suicide (Strand et al., 2016). Recently, it has been described in the USA as a measure of establishing the levels of musculoskeletal aptitude among children and adolescents, thus creating specific curves by age and sex related to gripping force and using them as health reference standards (Laurson et al., 2017).

In the realm of sports, the gripping force has been used as a measure of physical condition and it plays a big role in many sports. So, a weaker gripping force is related with a lower sport performance and the deterioration of motor skills. (Botonis et al., 2016; Cronin et al., 2017).

Due to all of the above, the gripping force has been widely used by researchers as a prediction value to establish the efficiency of therapeutic strategies (Roberts et al., 2011) and to evaluate the links to sports performance (Cronin et al., 2017).

Considering the present requirement to prove the efficacy of health related protocols, it is vital for health-related professionals to be able to count on evaluation tools that must be valid and reliable, in order to collect accurate and reliable data. To establish the therapeutic strategies efficiency, it is important to determine the goals of treatment, evaluate the patient and contribute to the development of the scientific research. Therefore, reliability studies are necessary to assure the validity of the evaluation tools (Amaral et al., 2012).

According to Fess (1986), reliability and validity are key to establish the effectiveness of an evaluation tool. The accuracy is defined as the degree in which the measurement is coherent and stable through multiple repetitions made, this is; error-free measuring (Atkinson and Nevill, 1998; Shechtman et al., 2005). The validity concept is understood as the device capacity to measure whatever is meant to be measured. This is why the main goal of validity is to create a valid criterion among tools so that both measurements define a similar standard.

Recent studies back up the hypothesis that low muscle force in adulthood predicts mortality due to all the causes, cardiovascular disease and cancer, both on healthy and unhealthy people (Ortega et al., 2012), therefore it should be one more prediction to take under consideration within the present health care system. Nowadays, in clinical practices, the gripping force can be used as a general muscle power predictive value.

Gripping force has traditionally been measured with manual dynamometers as the Takei®, a valid and reliable tool according Pearson's and test-retest correlation coefficient. Thus, the aim of this study was on one hand to evaluate the validity and reliability of the new MaxForce dynamometer versus the Takei®, to analyse the differences between both devices and spread the importance of the evaluation and muscle power treatment in the health care field.

MATERIALS AND METHODS

Subjects

The study participants were 49 men and 48 women aged between 19 and 25 (23.5 ± 3.47 years), with 85% of the sample claimed to be right-handed. None of the participants had any cognitive functional deterioration history, physical disability or upper extremities injuries. The study protocol followed the ethical standards of the International Helsinki Declaration.

Measures

Two dynamometers were used in this study, the MaxForce interactive dynamometer (Figure 1) and the Takei® manual dynamometer (Figure 2) in order to analyse the validity and reliability regarding strength measuring.

Each dynamometer was calibrated by the manufacturer and the calibration of each one of them was verified weekly. The technical features of each device can be found in Table 1.

Table 1. Technical Data

	TKK-5401	MaxForce
Radian Measure	0.5 a 100 Kg	0.1 a 300 Kg
Minimum Measuring Unit	0.1 Kg	0.1 Kg
Precision	± 2.0 Kg	± 0.100 Kg
Weight	0.660 Kg	0.880 Kg

Figure 1. Picture of dynamometer Maxforce, model 1.0.

Figure 2. Picture of Takei®, model TKK-5401.

Design and Procedures

The study goal and experimental procedure was explained to each subject both verbally and in writing followed by the signature of the consent agreement.

The study methodology design was based on the protocol conducted by Guerra et al. (2017) which consisted of two strength evaluations with a 10 minutes rest interval between them. The participants conducted a warm up prior to performing both strength evaluations and each exercise.

Each evaluation was made up of two sets of 3 isometric effort repetitions with a maximum length of 6 s and a resting interval of 2 min between repetitions, sets and devices in order to avoid accumulating muscle fatigue (Figure 3). The strength evaluation was done after the calibration procedures.

MAXFORCE	PRESS	3 x 6’ maximum repetitions 2’ pause between repetitions
	PULL 2’ pause between devices	3 x 6’ maximum repetitions 2’ pause between repetitions
TAKEI	LEFT HAND	3 x 6’ maximum repetitions 2’ pause between repetitions
10’ pause between evaluations	RIGHT HAND	3 x 6’ maximum repetitions 2’ pause between repetitions
TAKEI	LEFT HAND	3 x 6’ maximum repetitions 2’ pause between repetitions
	RIGHT HAND 2’ pause between devices	3 x 6’ maximum repetitions 2’ pause between repetitions
MAXFORCE	PRESS	3 x 6’ maximum repetitions 2’ pause between repetitions
	PULL	3 x 6’ maximum repetitions 2’ pause between repetitions

Figure 3. Strength evaluation protocol.

In the Takei® case, the muscle force was evaluated alternating both hands whereas in the MaxForce case we evaluated two different kinds of efforts, contraction and traction (press and pull). The subjects held the standard position detailed in the procedure. The complete protocol took around 30 min. The tests were provided by two examiners.

Each volunteer was randomly assigned a dynamometer and in the second round, the assignment was made in the same order. The same devices were used in both evaluations.

The study participants specific positioning protocol (Figure 3) throughout the testing was comfortably sitting down on a chair with no armrests with their feet completely on the floor, their hips and knees bent about 90 degrees measured with a goniometer. We used an adjustable seat to account for the favour subjects’ anthropometric differences.

To collect the data in the Takei® device, we followed the standard procedure recommended by the American Society of Hand Therapists (Fess, 1992), the shoulder of the rehearsed extremity was adductioned and turned in a neutral way, the elbow was bent 90 degrees, the forearm in a neutral position and the wrist dorsiflexed into somewhere between 0 and 30 degrees and between 0 and 15 degrees of ulnar deviation.

In the case of the MaxForce dynamometer, the subjects were placed with their back up straight, the feet were placed under their hips and their knees were bent at 90 degrees, their elbows were tucked next to their bodies and the MaxForce was placed about 10 cm in front of their navel.

For both devices tests, the subjects were instructed to maintain their positions throughout the isometric strength test. They were warned, instructed and corrected by the tests administrators as needed.

All subjects were subjected to demonstration and familiarization attempts. To avoid muscle substitution patterns, the subjects were measured by tape and goniometer to reach an optimal position. To ensure the consistency of the measurements, the subjects were not trained during the test and only standardized verbal instructions were given. The tests were performed individually and the digital displays of the dynamometers were covered so that they could not be seen and they were not provided with any visual or auditory feedback to avoid a competitive environment that could interfere with the interpretation of the data.

The ability of the subject to follow these indications showed a correct cognitive functioning to take part in this study. The standardized verbal instructions were as follows: "This task will test your strength. Whenever I say “go”, please make your maximum effort in a smooth and progressive way for 6 s and continue until I tell you to stop. You will be given a 2 min rest interval after every repetition of maximum strength. Three repetitions with each hand will be completed using the Takei® device, and there will be three repetitions for each type of effort, compression and traction with MaxForce dynamometer. You will be given a rest period of two min and then another three repetitions will be completed by changing the instrument. A ten min recovery period will be given and the entire protocol will be repeated. Stop immediately if you feel any unusual pain or discomfort at any time during the test. Do you have any questions? Are you ready? Go!" The standard verbal reinforcement was, "Harder! ... Harder! ... Relax."(Mathiowetz et al., 1984).

Statistical Analysis

Mean and standard deviations were calculated for the mathematical expression of maximum force. In case of the manual dynamometer, we opted for measuring the strength in both hands since the instruments of our study are different in the bilateral concept of force.

We performed five monthly calibration verifications to determine the consistency and measurement accuracy of the instruments.

An analysis of repeated measures of ANCOVA covariance was performed to verify the possible differences between the measurements taken by the dynamometers. The factor between subject, age and gender were controlled as covariates given that they affect strength. The reliability of both the instrument and the observers was evaluated using the Intraclass Correlation Coefficient (ICC). The reliability and concurrent validity were evaluated with the retest test. The measurement error was expressed as a percentage. The level of significance that was chosen was $p < 0.05$.

RESULTS

The descriptive statistics for force measurements for male (n = 49) and female participants (n = 48) are presented in Table 2. The mean correlation between the strength of both hands for Takei® device was 0.7856.

Table 2. Takei® grip strength measurements for men (n = 49) and women (n = 48) in relation to the right and left hand. Kilograms (Kg), standard deviations (SD)

	Takei®	
	Right (SD)	Left (SD)
Men	44.28 Kg (8.08)	41.16 Kg (6.52)
Women	27.05 Kg (6.44)	25.56 Kg (6.35)

The average measurement error for the MaxForce dynamometer was 1.72% and for the Takei® device 5.38%, which indicates that MaxForce has a higher measuring accuracy. Likewise, the reliability between evaluators of the MaxForce dynamometer was perfect (r = 1.0) due to the digital reading.

The test-retest reliability between the three measurements was very high, both for the MaxForce device (r = 0.9617) and for Takei® (r = 0.9763). The test-retest reliability between dynamometers was high for both the MaxForce dynamometer (r = 0.9864) and for Takei® (r = 0.9853), suggesting that the force data were stable in all three measurements for both instruments. The concurrent validity between the dynamometers was very high for both MaxForce (r = 0.9968) and TKK-5401 (r = 0.7856). The measurement of error and reality data between dynamometers is presented in Table 3, and the reliability and validity of the two instruments in Table 4.

Table 3. Measurement of error and reliability data between dynamometers and the three measurements

	MaxForce	TKK-5401
Average Measurement Error	1.72%	5.38%
Reliability between Instruments	0.9864	0.9853
Accuracy between measurements	0.9617	0.9763

Table 4. Reliability and validity of the instruments MaxForce and TKK-5401

		Reliability	Validity
MaxForce	Mean (SD) ICC (CI, 95%)	0.9864	0.9968
TKK-5401	Mean (SD) ICC (CI, 95%)	0.9853	0.7856

Significant differences were found ($p < 0.05$) in the values obtained between MaxForce and Takei® ($F = 6.00$, $p = 0.016$), between genders ($F = 235.387$, $p = 0.001$) and between ages ($F = 4.277$, $p = 0.041$). The results of repeated measurements are represented in Table 5.

Table 5. Results of repeated measurements and the influence of the gender and age factors

Source	Factor	Probability
Variation of the repeted measurements (1, 2 and 3) between subjects	Between instruments (MaxForce y TKK-5401)	0.016*
Variation due to the main effect	Gender: F=7.8044 Age: F=4.659	0.002*

**P < 0.05 significative differences*

DISCUSSION AND CONCLUSIONS

The main objective of the study was to verify the accuracy, reliability and validity of the new MaxForce interactive dynamometer making a comparison with an instrument used and accepted by the scientific community for the measurement of force, the manual Takei® device.

The calibration tests indicated that both devices kept, without distortions, the mechanical characteristics of the manufacturer and although the equipment used is different, the measurements can be considered as equivalent, considering that the calibration load was the same for both dynamometers regardless of its characteristics.

This study provides high values of precision, reliability and validity for the MaxForce dynamometer, confirmed with repeated measures between subjects and a very high significance of the data. This confirms the hypothesis that MaxForce is a very reliable scientific instrument giving the verifiability of the data it is supplied with, being usable for sanitary, sports and research purposes. On the other hand, MaxForce has a great validity, surpassing many other instruments that have not been put through the phases of scientific validation in such a meticulous way, making the MaxForce a valid instrument for the evaluation of the strength in humans.

No statistically relevant differences were observed among measurement validations between both dynamometers. The differences between the two can be related to the different means of force transmission. We found that the Takei® dynamometer allows a unilateral force measurement and the MaxForce instrument can provide both unilateral and bilateral measurement. When examining the scientific literature we find that the development of strength from childhood to adulthood has a symmetrical development, so that tools such as MaxForce, would be preferable for the design of training programs to improve sports performance, rehabilitation (Gerodimos et al., 2013) or health itself (Laurson et al., 2017).

Unlike the manual dynamometer, which measures muscle strength in a single muscle, MaxForce allows the measurement and training of multiple muscle groups, being able to make a more complete, more precise and more accurate measurement of the real strength of a subject. It is for this reason that in people with pathologies, such as rheumatoid arthritis where the evaluation is difficult with electronic hand-held dynamometers (Massy-Westropp et al., 2004), MaxForce allows a more complete assessment of strength and being an isometric exercise it avoids joint stress (Rio et al., 2015).

A comparative study of several devices measuring gripping force suggested that, although they are valid methods for the detection of pathology, they are not sensitive to small changes that can serve as indicators of a disease, concluding that instruments with greater precision are needed to perform these evaluations (Kurillo et al., 2004).

Although additional studies with different samples are needed to confirm these findings, our results show that the MaxForce dynamometer can be used to accurately perform strength tests in healthy subjects and could be used in the screening, early detection and diagnosis, as well as the treatment of different diseases.

The clinical use of tools such as MaxForce should be critically considered, mainly due to the need for calibration before the isometric force evaluations and also the use of a standardized protocol can improve the scope and precision of the measurements, allowing future comparisons between different populations or pathological conditions.

In addition to this, one more factor to be taken into account is the level of investment required, both dynamometers are suitable for tests that are carried out in clinical practice or in ambulatory environment because of their low cost. In addition, MaxForce provides graphic visualization and continuous recording of force during the test.

If we review the current scientific literature we'll find that isometric force training is effective in the treatment of hypertension (Inder et al., 2016, Carlson et al., 2014) and the prevention of heart disease (Carlson et al., 2014; Grøntved et al., 2015; Kamiya et al., 2015), in the improvement of bone density, general flexibility and joint mobility (Heinonen et al., 2013; Yousefi et al., 2012), in the reversal and prevention of sarcopenia (Roubenoff, R. 2000), in the improvement of the quality of life and prognosis of multiple sclerosis (Citaker et al., 2013) and Parkinson's disease (De Oliveira et al., 2008), in the reduction of risk and symptoms of osteoarthritis (Anwer and Alghadir 2014) and in chronic muscular pain relief (Cagnie et al., 2007; Van Wilgen et al., 2003).

The clinical importance of this study is firstly due to the need to act against the expansion of the elderly population and the current epidemy of chronic diseases and secondly, to assure that the evaluation instrument used is valid and reliable, as the results have shown, for any type of work strength training and health evaluations.

Given the important association of muscle mass and strength with survival in older subjects, physicians, personal coaches and health specialists should use tools, such as the MaxForce dynamometer for strength measuring and training.

Likewise, the MaxForce dynamometer consists of a simple, objective, practical, quick, easy to use and inexpensive procedure, which together with its remote control and mobile application with audiovisual feedback can turn it into an ideal system to enhance adherence to training and therefore induce health improvements.

MaxForce holds an added value, for the complete evaluation of the musculature. Making this device a practical and functional system to improve adherence and motivation for training. In addition the integrated collection of data and comparative analytics software provides an increasing more accurate prediction of biological age and risk factors. Its implementation in the health system could contribute to the improvement in people's general health and improve treatment of multiple pathologies treatment, being the subject of future research which may concern different populations and adding measurement instruments such as electromyography and others.

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