ORIGINALNI ZNANSTVENI RAD

USPOREDBA MJERENJA SNAGE M. QUADRICEPS UPORABOM STANDARDNOG MANUALNOG I FIKSNOG DINAMOMETRA

COMPARISION OF STANDARD MANUAL AND FIXED DYNAMOMETER DURING QUADRICEPS MUSCLE STRENGTH TEST

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ABSTRACT

Muscle strength assessment using dynamometry is a very important parameter in clinical practice to set normative values in a healthy population and monitoring the improvement or exacerbation of pathological conditions of joint structures. Using dynamometry, the peak force of the quadriceps muscle was measured preciesly in order to achieve the main goal of the research which is to compare two dynamometers by testing the muscle strength of the quadriceps muscle at 15° and 90° flexion of the knee joint and to see the advantages and disadvantages of each dynamometer by conducting a questionnaire. The devices used in the research are a standard manual dynamometer, microFET®2 and fixed dynamometer, EasyForce®. In addition to the dynamometers, a questionnaire was also used. The fixed dynamometer registered higher peak values of the forces in all positions and angles of the joint and the statistically significant difference was shown in measurements at 15° flexion in the supine position (P=0,022) and at 90° flexion in both sitting (P<0,001) and supine position (P<0,001). The position in which was easiest for the respondents to act against the resistance was at 90° flexion with the fixed dynamometer in a sitting position and pain during the testing was reported with a standard manual dynamometer. The respondents stated that the equipment of the standard manual dynamometer was better, while the objectivity went in favor of the fixed dynamometer. Applicability went in favor of the standard manual dynamometer, while a fixed dynamometer give more precise results.

Key words: dynamometry, fixed dynamometer, knee joint, quadriceps femoris muscle, standard manual dynamometer

SAŽETAK

Procjena mišićne jakosti vrlo je važan parametar u kliničkoj praksi za postavljanje normativnih vrijednosti kod zdrave populacije i praćenja poboljšanja ili pogoršanja patoloških stanja struktura zgloba. Pomoću dinamometrije, mjerena je vršna sila četveroglavog natkoljeničnog mišića upravo kako bi se ostvario glavni cilj istraživanja, a to je usporediti dva dinamometra ispitivanjem mišićne jakosti četveroglavog natkoljeničnog mišića pri 15° i 90° fleksije koljenog zgloba te provedbom anketnog upitnika uvidjeti prednosti i nedostatke pojedinog dinamometra. Uređaji korišteni u istraživanju su standardni ručni dinamometar, microFET®2 i fiksni dinamometar, EasyForce®. Uz dinamometre, koristio se i anketni upitnik. Fiksni dinamometar je registrirao veće vršne vrijednosti sila u svim pozicijama i kutovima zgloba, a statistički značajna razlika pokazala se pri mjerenju u ležećoj poziciji pri 15° fleksije koljenog zgloba (P=0,022), te pri 90° fleksije koljenog zgoba u sjedećoj (P<0,001) i ležećoj poziciji (P<0,001). Položaj u kojem je ispitanicima najlakše bilo djelovati protiv otpora je pri 90° fleksije s fiksnim dinamometrom u sjedećoj poziciji, a bol tijekom testiranja prijavljena je sa standardnim ručnim dinamometrom. Ispitanici su izjavili da je oprema standardnog ručnog dinamometra bolja, dok je objektivnost išla u prilog fiksnog dinamometra. Ako se promatra aplikativnost aparata, prednost možemo dati standardnom ručnom dinamometru dok preciznije rezultate daje fiksni dinamometar.

Ključne riječi: četveroglavi mišić natkoljenice, dinamometrija, fiksni dinamometar, koljeni zglob, standardni ručni dinamometar

INTRODUCTION

The knee joint is the largest and most complex joint in the human body and with its complex structure, which includes active and passive stabilizers, transfers body weight from the thigh to the lower leg, and in a dynamic sense, serves for walking and other ways of human movement in space (1). The stability of the knee joint comes from passive and active stabilizers; ligaments are passive, while active stabilization includes muscles whose function is based on two components; muscle strength, i.e. the peak force that certain musculature can produce by its contraction, and muscle power which is defined as the result of peak force production in a certain time interval (2). In order to obtain the parameters of the maximum peak values of the forces of any musculature, a biomechanical method called dynamometry has been used.

In practice, different types of dynamometers inherent in handheld dynamometry (HHD) are used. The most often used is standard manual dynamometer or push dynamome-

ter that is attached to the segment of the subject and stabilized by the examiner's hand (3). Nevertheless, portable fixed dynamometer or pull type is fixed at one end to the segment of the subject and to the stationary surface the other end (4) and dynamometer for measuring hand grip strength that is independent of the examiner. The advantages of handheld dynamometry is working with patients of various conditions and diseases. The biggest disadvantages of manual push dynamometry have been described in numerous studies, which have shown that the primary disadvantage is the weakness of the examiner. Weakness depends on the age, sex and experience of the examiner, but the authors state that experience is not a factor that affects the weakness of the examiner, but that only strength and stabilization abilities can relatively influence the resistance of the examiner (5). The theory that is generally accepted in the literature is that during the measurement, the examiner must assess whether he can provide adequate resistance or not, because if examiner doesn't realize this on time, the muscle contraction by the subject is no longer isometric, becomes isotonic and the measurements are not valid (6).
Previous research has been mostly carried out on isokinetic dynamometers, and some comparisons have been made of an isokinetic dynamometer with a standard manual dynamometer or a comparison of an isokinetic dynamometer with a fixed dynamometer, but, so far, no research has been carried out comparing two different dynamometers that belong to the same category, handheld dynamometry (HHD). Given that the standard manual dynamometer is represented in clinical practice with the appearance of a new fixed dynamometer and the lack of literature, it was important to show, through four main goals, whether there is a statistically significant difference in the registration of muscle strength data between the standard manual and fixed dynamometer at 15° and 90° flexion of the knee joint in a sitting and supine position, which is extremely important and necessary for obtaining more precise and objective measurements, considering that the standard manual dynamometer is linked to evidence that although it is easy to use, due to the influence of intrinsic factors, the results of muscle strength that are registered they are not precise. Furthermore, through the questionnaire, another goal of the research is to determine the subjective feeling of the respondents about the applicability of dynamometers.

The research itself contributes to the profession due to the lack of literature and to better demystify the advantages and disadvantages of using dynamometers for clinical and educational purposes.

MATERIALS AND METHODS

Respondents

The quantitative research was conducted in April 2022 at the Faculty of Health Studies of the University of Rijeka for the purpose of writing the final thesis. Due to easy accessibility, the study population was a convenience sample of college students of the Undergraduate professional study of Physiotherapy, Faculty of Health Studies of the University of Rijeka. This sample consists of 20 subjects, male and female, between the ages of 18 and 23. Exclusion criteria for this research included having chronic diseases, any type of recent knee joint injuries, or injuries of the surrounding structures next to the joint. These subjects were excluded from the study due to safety and prevention of additional injuries during testing. The subjects were informed about the objectives of this study and the necessary information related to the study's ethics. All subjects read and signed the "Informed Consent to Participate in the Research" in which it is emphasized that their participation is voluntary. The study was approved by the statement from the mentor on the ethics of low-risk research. Given the non-invasive nature of the measurements, no permission from the Ethics Committee of the Faculty of Health Studies of the University of Rijeka was required.

Methods

Two dynamometers were used to measure quadriceps muscle strength: a standard manual dynamometer, microFET®2, from Hoggan Scientific, LCC, United States of America and a fixed dynamometer, EasyForce®, from Meloq AB, Stockholm, Sweden. Both devices are standardized and licensed, with the fact that the EasyForce® device from Meloq AB was given to the Faculty of Health Studies of the University of Rijeka for test use. In addition to the dynamometer, which was used to obtain muscle strength parameters, a questionnaire was conducted among the subjects, according to which the advantages and disadvantages of each dynamometer were seen.
Before the actual testing, basic information was taken from the subjects about their gender, age, height, body weight, dominant leg, playing sport or any recent injuries or illnesses. Muscle strength testing was performed in a sitting and supine position at 15° and 90° flexion of the knee joint.
The first measurement was performed with a standard manual dynamometer in a sitting position at 90° flexion. The subject was in a sitting position on the table, with 90° knee flexion, hands resting on the floor, torso upright. The dynamometer was placed on the distal part of the lower leg just above the upper ankle joint. Given that quadriceps is an extremely strong muscle, there was a high probability that when measuring with a standard manual dynamometer, the examiner would be pushed away by the subject. Precisely because of this, the examiner had to lean against the wall and thus provide maximum resistance. The subject attempted to perform a knee extension movement, resisting the examiner's resistance for 5 seconds. The same procedure was performed in a sitting position under 15° of flexion with a standard manual dynamometer, given that before placing the dynamometer, the exact angle of the joint was measured with a goniometer.
The fixed dynamometer procedure included additional equipment: a cuff with a hook placed around the upper ankle to which one end of the dynamometer was attached, and the other to a metal chain tied around the table.
The procedure was the same for the sitting position as for the standard manual dynamometer at 15° and 90° flexion angles, and before the start, the dynamometer was reset to 0 N. In the supine position, it was important to eliminate the movements of other parts of the body, primarily the hip joint of the other leg and the lumbar spine. In this case, another examiner fixed the subject's pelvis in a supine position. All subjects received verbal support during testing and action against resistance.
After testing each subject, the questionnaire was filled out. The used questionnaire was not standardized, but it was designed for the needs of this research. It consists of three open-ended questions to which subjects answered individually (Attachment 1).

Statistical evaluations

The data of the quadriceps muscle strength measurements were processed by calculating the significance of the difference between the arithmetic means of the variables using the Student's t-test for independent small samples in Statistica 14.0.0.15 program by TIBCO Software Inc. Descriptive statistics were used to calculate the arithmetic mean (M), standard deviation (SD) and frequencies and the level of statistical significance shown as $P<0.05$.

Data on the advantages and disadvantages of a particular dynamometer were obtained through the questionnaire. Answers from the questionnaire are expressed in frequencies.

RESULTS

Table 1. Characteristics of respondents (n=20)

Variables	M ± SD	Range (Min-Max)
Age	19,75 ± 1,25	18-23
Height (cm)	174,62 ± 7,16	161-186,5
Body weight (kg)	69,7 ± 10,76	51-97

20 respondents aged 18 to 23 participated in the study, of which 11 men and 9 women. 17 respondents state the right leg as dominant, while in three respondents the left leg is dominant.

Table 2. Comparison of the results of measuring the muscle strength of the quadriceps muscle between a standard manual and a fixed dynamometer at 15° flexion of the knee joint in a sitting position.

microFET®2		EasyForce®		P-value
M	SD	M	SD	P= 0,056
230,02	54,61	300,62	150,94	

Table 3. Comparison of the results of measuring the muscle strength of the quadriceps muscle between a standard manual and a fixed dynamometer at 15° flexion of the knee joint in the supine position.

microFET®2		EasyForce®		P-value
M	SD	M	SD	P= 0,022
238,06	46	314	134,55	

Table 4. Comparison of the results of measuring the muscle strength of the quadriceps muscle between a standard manual and a fixed dynamometer at 90° flexion of the knee joint in a sitting position.

microFET®2		EasyForce®		P-value
M	SD	M	SD	P < 0,001
316,19	69,73	570,12	250,5	

Table 5. Comparison of the results of measuring the muscle strength of the quadriceps muscle between a standard manual and a fixed dynamometer at 90° flexion of the knee joint in the supine position.

microFET®2		EasyForce®		P-value
M	SD	M	SD	P < 0,001
237,38	38,29	609,53	211,41	

Tables 2, 3, 4, 5. show comparisons of the results of measuring the muscle strength of the quadriceps muscle between a standard manual and fixed dynamometer at a certain degree of flexion of the knee joint and the subject's position. The values of the arithmetic means of the variables were compared. Arithmetic means were obtained by summing the mean value of all 20 subjects from three consecutive peak force measurements for each subject. When comparing the results of quadriceps muscle strength at 90° flexion of the knee joint in a sitting and supine position, the P value obtained by calculation took on a very small value ($P=0.000094$ for measurements at 90° flexion in a sitting position and $P=0.000000$ for measurements at 90° of flexion in the supine position) therefore the P value for the above two comparisons is shown as $P<0.001$. Results of muscle strength, as values of arithmetic means and standard deviations, are presented in newtons (N).

Table 6. Presentation of the number of respondents who answered the questions from the questionnaire through these three categories.

Categories		microFET®2	EasyForce®
Easiest action against the resistance	15° flexion, sitting position	0	0
	15° flexion, supine position	0	2
	90° flexion, sitting position	0	15
	90° flexion, supine position	0	3
Pain during testing	15° flexion, sitting position	4	2
	15° flexion, supine position	5	6
	90° flexion, sitting position	1	0
	90° flexion, supine position	2	0
Subjective opinion about dynamometers	Better equipment	11	9
	Shorter duration of testing	20	0
	Precision and functionality	0	20

DISCUSSION

Cha (2014) state that the maximal isometric activity of the quadriceps femoris muscle with dorsiflexion in the upper leg joint, measured by electromyography, showed higher peak force values in comparison if the upper leg joint was in plantar extension or in a neutral position, due to the action of mechanical forces around the knee joint created by tibialis anterior muscle (7). In this research, during the isometric muscle contraction, the position of the upper ankle joint was not controlled, so the subjects could have the upper leg joint in any of the positions during the contraction, this reduced control of the upper leg joint could greatly influence the results of the peak forces registered by both dynamometers. That is why it is important to emphasize that during the measurement of peak force, attention should be paid to the muscles located around the primary measurement joint, in this case the knee joint, and to the muscles that cross several joints, including the upper ankle joint and the hip joint. In comparison with the aforementioned study, in this study only the peak force of the quadriceps femoris muscle was measured without electromyographic analysis and an isokinetic dynamometer, and higher peak force results may indicate that the supine position is more stable for the subject, which also confirms the conclusion of other authors stated, when the trunk is not fixed in a sitting position, performing an extension in the knee joint becomes more difficult because the fixation of the pelvis and the upper leg in the proximal part becomes worse (8). Also, the conclusion from the study (4) indicates that in the supine position the reliability and validity of the measurement of the strength of the quadriceps femoris muscle increases primarily if the muscle strength is measured with a fixed portable dynamometer, while in the sitting position it has been proven that the isometric force of knee extension increases when the trunk is stabilized and that approximately 70% of the maximum force was shown when stabilization was provided by the weight of the body on the surface of the table (9).

The results of measuring muscle strength will vary greatly if measured with different devices. The obtained results indicate that in all grades and in each position, according to the arithmetic means of the variables, higher values were registered by the fixed dynamometer. The results from the literature coincide with these results. Mentiplay et al. (2015) indicated that handheld portable dynamometry showed moderate to good reliability for measuring muscle strength, but the problem they pointed out in their research is that this good reliability with a standard manual dynamometer is the result of registering greater muscle strength due to poor stabilization of the device, and the fact that it is very likely that the muscle contraction changed from isometric to isotonic concentric contraction and that the subject had an initial rapid increase in strength before the start of the measurement. They advise that for future measurements of the quadriceps femoris muscle, a stabilized dynamometer should be used referring to a fixed dynamometer or isokinetics (2). Hansen et al. (2015) conducted their research with a standard manual dynamometer, microFET®2, where the authors highlighted the discomfort and pain that occurs on the tibia during a standard procedure where the examiner provides resistance to the subject while the dynamometer is placed against the distal part of the tibia (10). Since the authors did not have a fixed dynamometer to compare the results with, they decided to fix a standard manual dynamometer with a belt and foam pad to compare the results with an isokinetic dynamometer. Results indicated that fixation of a standard manual dynamometer reduced discomfort during testing, resulting in measurements that were not statistically significantly different from the isokinetic dynamometer (10). The authors of numerous studies point out that standard manual dynamometry is an excellent choice for clinicians who need quick and regular monitoring of muscle strength, but these results also become imprecise if the examiner does not have enough strength to resist the quadriceps femoris muscle (11). Research that studied fixed dynamometry (3,12,13) indicates the advantages of handheld dynamometry in the form of objectivity when registering results, but also some disadvantages. Sung et al. (2019) state that during the use of a fixed dynamometer, certain infrastructure of the room where the measurement takes place is required; that the dynamometer can be attached to the wall or next to the table or the fixation must be constantly moved when testing other musculature, which affects the time duration of the test, but also, if one wants to start using fixed dynamometry for clinical purposes, it would be difficult as well given that these are patients in beds (12). In order to solve the infrastructure problem related to the application of a fixed dynamometer, González-Rosalén et al. (2021) suggest and propose the fixation of one part of the fixed dynamometer to the examiner's body, which they also proved through research; the method showed excellent reliability between the measurement results and the examiner's body profile (3). The latest research from 2022 is related to the fixed dynamometer, EasyForce®, and was carried out by authors from the universities of Slovenia and Serbia. The main goal of their research was to show the reliability of recording results by a fixed dynamometer and compare it with a standard handheld dynamometer. According to their results, the authors found that EasyForce® provides reliable data for the assessment of isometric muscle strength of the knee flexors and extensors, which supports the use of a dynamometer, in contrast to the results of measurements with a standard manual dynamometer where studies have proven lower values and poor results of peak muscle forces (13).

The results of the survey questionnaire partly comply with the results from the literature which gives preference to the application of the fixed dynamometer over the standard manual dynamometer. Subjects estimated their subjective opinion about dynamometers through three questions that included specific categories. Most subjects' answer to the first question, "In which position and at what angle was it easier for you to act against the resistance?", was that it was easiest to act against the resistance in a sitting position at 90° flexion of the knee joint with a fixed dynamometer. The reason for this, from a biomechanical point of view, is that the muscle has the most efficient action at the right angle of the joint. Another reason is the fixed dynamometer, which was fixed and thus enabled true isometric muscle contraction. Also, the lack of stabilization in the sitting position, which could also affect easier action against resistance and does not match the results from the literature that state that if the trunk is not stabilized in a sitting position, acting against the resistance becomes more difficult (8). However, in this research, due to the compensations mentioned by the subjects, it was easier for them to act against the resistance in a sitting position at 90° flexion of the knee joint with fixed dynamometer. In the case of the majority of respondents, the most common compensations were the activation of the opposite flexor muscles of the hip joint and the tilting of the trunk to the side and forward. On the other side, some respondents stated it was easiest to act against resistance in the supine position at 15° and 90° flexion of the knee joint with a fixed dynamometer. The explanation may be in better stabilization in the supine position, with small compensations in the form of an increase in lumbar lordosis, and due to the fixation of the fixed dynamometer by means of which they are able to act better against resistance. None of the subjects found it easier to act against the resistance of the standard manual dynamometer, which is to be expected considering that the subjects remarked that the standard manual dynamometer was not precise. During the measurement with a standard manual dynamometer, it is felt that muscle contraction is no longer isometric at one point, but becomes an isotonic concentric contraction, which greatly affects the measurement with the strength of the examiner, which agrees with the results of Mentiplay et al. (2). The second question, "Did you feel any discomfort or pain during the test? If yes, when?", partially divided the subjects. Most subjects felt pain at 15° in the supine position with a fixed dynamometer. The subjects stated that they felt a tightening at the splinter; strong muscle spasms due to what they say is an "unnatural leg position" and pain in the muscles in the back of the thigh. Other subjects have different opinions, but in this question category, unlike the last one, more votes were for the occurrence of pain during strength measurement with a standard manual dynamometer. All subjects commented on the pain that occurred due to the pressure of a standard manual dynamometer on the bone during resistance, and they stated that as the resistance of the examiner increased, so did the pain in the tibia. Also, some of the subjects admitted that because of the mentioned pain, they felt that the examiner was stronger and began to ease with the contraction. The above facts comply with the research results (10), but the authors offer solutions for this problem that will greatly facilitate measurements with this type of dynamometer. The subjects were asked to answer the third question, "In your opinion, which dynamometer proved to be more suitable for testing and measuring muscle strength?", through their experience during testing. The first category in this question included the opinion on the equipment of a particular dynamometer. An interesting fact is that more subjects were in favor of the standard manual dynamometer equipment, which they found to be simpler. The equipment of a standard manual dynamometer includes three types of attachments that are intended for a certain part of the body, and adapted to the screw on the dynamometer itself before the measurement, which is quick and efficient and does not take much time. The equipment of the fixed dynamometer is more complex and numerous, it consists of hooks attached to each end of the dynamometer, chains, belts around the joints and belts for measuring the muscle strength of the flexors and extensors of the trunk, however, regardless of the complexity and choice of equipment, setting everything up is quite complicated. In addition to the above, for the measurement of certain musculature, it is required that the room where the measurement takes place has a certain infrastructure, which is impossible, but the authors also offer a solution to this problem, that is, to fix one end of the dynamometer to the examiner's body, and the research results have shown excellent reliability (3). The analysis of the equipment of an individual dynamometer led the subjects to the answer that the test duration was shorter with a standard manual dynamometer, which is justified considering its equipment and the equipment of a fixed dynamometer. All subjects were unanimous in their answers and believe that the time duration of the test is very important considering that it will never be necessary to measure the strength of only one musculature in a patient, child, or athlete, but rather several groups. In order to save time, speed and work, preference is given to a standard manual dynamometer. The subjects believe that the equipment of the fixed dynamometer could be simplified and made of a stronger material, because the material of the equipment broke during the muscle strength test. On the other hand, regarding the last category of the third question, which concerns objectivity, advantage was given to the fixed dynamometer primarily because the measurement results do not depend on the strength of the examiner, the dynamometer is fixed, does not move during the measurement, and does not cause pain. The subjects agree that the precision of the results is very important in clinical work in order to monitor the phases of improvement or deterioration of various conditions, but also, as the authors state, objectivity is important for setting normative values of muscle strength in a healthy population (13).

CONCLUSIONS

Both dynamometers belong to the category of handheld dynamometry and they are financially accessible. The main advantage of the standard manual dynamometer is its applicability, portability and time saving, while the disadvantage is the possibility of displacement during movements and pain during testing. The main advantage of a fixed dynamometer is a more accurate measurement due to the impossibility of moving the device during testing. Potential disadvantages are related to the equipment which is made of weak material but also a longer preparation of space and equipment. It is necessary to conduct additional research, primarily due to the small number of subjects, but also the lack of literature. It is up to researchers and manufacturers to investigate how to provide a higher quality equipment and perform measurements of muscle strength with patients, athletes and children.

ATTACHMENT 1.

Questionnaire

1. In which position and at which angle was it easier for you to act against resistance?
2. Did you feel any discomfort or pain during the test? If yes, when?
3. In your opinion, which dynamometer proved to be more suitable for testing and measuring muscle strength?

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