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INFLUENCE OF HOME EXERCISE PROGRAMME ON THIGH MUSCLE TONE AND FUNCTION OF KNEE JOINT BEFORE TOTAL KNEE ARTHROPLASTY

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ABSTRACT

The aim of the study was to investigate the effect of 8-week home exercise programme (HEP) on thigh muscle tone in patients with knee joint osteoarthritis (OA) before total knee arthroplasty (TKA). Fifteen female patients with knee joint OA aged 50–74 years who were scheduled to TKA participated in the study before and after 8-week HEP. Muscle tone (frequency of muscle oscillation), elasticity (logarithmic decrement of muscle damped oscillations) and stiffness of *rectus femoris*, *vastus medialis* and *vastus lateralis* muscles were measured using hand-held myotonometer Myoton 3. Self-reported assessment of knee joint function and pain was performed using Western Ontario McMaster Universities Osteoarthritis Index (WOMAC). Significant ($p<0.05$) decrease in muscle tone and stiffness of *vastus lateralis* muscle was noted after HEP, but no change was observed in elasticity of the muscle. Also no significant difference was found in *rectus femoris* and *vastus lateralis* muscles in either tone, elasticity or stiffness. As a result of 8-week HEP, pain intensity in knee joint decreased, whereas self-reported function of knee joint by WOMAC did not improve significantly. Preoperative performance of HEP is recommended for improvement of surrounding knee joint muscle function.

Keywords: *osteoarthritis, muscle tone, home exercise programme, WOMAC index*

INTRODUCTION

Osteoarthritis (OA) is one of the most common diseases affecting joints and causing loss of functional ability among elderly people and the disease most commonly affects knee joints. The risk factors of the disease are age, female gender, obesity, trauma, genetical predisposition and muscle weakness. The main symptoms are pain, joint stiffness, swelling, joint instability and muscle weakness, which can lead to impaired physical and emotional condition and reduced quality of life [5, 3].

Total knee arthroplasty (TKA) is an intervention for people with severe OA when conservative therapy has no effect. Patients often have to wait several months for the surgery and during that time they endure severe pain that restricts their activities of daily living (ADL) and participation in their normal social roles. Pre-operative interventions such as exercises are performed in the expectation of improving pre-operative outcomes as well as recovery after surgery [20]. There is much evidence suggesting that exercises are effective in OA patients for decreasing pain and improving function [5, 3]. Not much research has been done about the effect of exercises in OA patients waiting for knee replacement surgery [20].

There is no evidence in the literature about muscle tone measurement in OA patients.

Muscle tone of *quadriceps femoris* muscle has been previously studied in healthy older males [1] and adult male basketball players [12], as well as other lower limb muscles in young male athletes [10, 11]. There has been one study that investigated muscle tone of *quadriceps femoris* muscle after arthroscopic partial menisectomy in males and females [6]. However, muscle tone is a very important criterion, when determining the function of the skeletal muscle [21, 19]. A special device for measuring muscle tone – myotonometer – was developed at the University of Tartu. Its validity and reliability have been scientifically proven [4, 22]. The working principle of the device is based on recording the damped oscillation of tissue after a short calibrated mechanical impulse on the muscle belly [1, 18].

The aim of the present study was to investigate changes in thigh muscle tone and function of knee joint in OA patients waiting for TKA before and after an 8-week home exercise programme (HEP).

MATERIALS AND METHODS

Subjects

Thirteen female patients aged 50–74 years with late stage of knee joint OA who were scheduled for total arthroplasty of the knee joint volunteered to participate in the study. The mean±SD age of the patients was 62.3±7.2 years, body mass was 91.3±15.9 kg and body mass index was 34.7±6.0 kg/m^2. The subjects were scheduled to surgery and evaluated by orthopaedic surgeon in the Department of Orthopaedics and Traumatology of Tartu University Hospital. The exclusion criteria were other musculoskeletal diseases, neurological diseases and diseases affecting balance and coordination. On the day of the assessment the subjects had not taken any inflammatory or pain relieving medication and all testing was conducted in the morning time from 9 to 11 am. Before the beginning of the testing session, all subjects completed an informed consent form. The study carried the approval of the Ethics Committee of the University of Tartu. The testing was performed in the Laboratory of Kinesiology and Biomechanics of the University of Tartu twice – before and after the 8-week HEP.

Measures

Clinical investigation

The subjects' clinical investigation was performed by orthopaedic surgeon (TH) in the Department of Orthopaedics and Traumatology of Tartu University Hospital. Knee joint osteoarthritic changes were evaluated in X-ray imaging and patients with late stages of OA (stage III–IV according to Kellgren and Lawrence [8] classifications) who were scheduled for knee joint replacement and had no above mentioned exclusion criteria were recommended for participation in the present study.

Exercise programme

The preoperative therapeutic HEP was mostly oriented to muscle strengthening exercises with elastic band (Thera-Band, System of Progressive Exercise, US), stretching, balance and walking exercises. At the first meeting the physiotherapist (JS) explained the exercise programme to the patients, gave them the elastic band set, the printed exercise programme with pictures and explanations, and diary. In the diary they recorded how many times per day they did each exercise, training time, perception of pain before and after the HEP, perceived intensity of the exercise and fatigue during the exercises using modified Borg scale, time spent in outdoor walking, and the number of stairs walked during the day. Once a week the physiotherapist called the patients on the phone, and asked them about HEP and problems with the knee. The

patients performed the HEP once a day during 64 days (whereas one patient did the exercises twice a day) on the average with mean exercise time duration of 35 min.

Muscle tone measurement

For muscle tone, elasticity and stiffness characteristics investigation the hand-held myotonometer Myoton 3 (Müomeetria Ltd, Estonia) was used [13, 15, 17]. The working principle of device is based on dosed impact on muscle belly, after which a muscle as viscous-elastic structure reply with damped oscillation. The muscle tone is characterized by frequency of muscle oscillation [Hz]. The muscle elasticity, i.e. the ability of the muscle to restore its initial shape after contraction, is characterized by logarithmic decrement of oscillations' amplitude damping [14, 16]. Muscle with high elasticity has lower logarithmic decrement value. Stiffness of muscle characterized the ability of tissue to restore its shape after removing of external force acting on muscle. Myoton 3 has mass of testing end 18 g and it induces oscillation of muscle tissue by a mechanical impact with minimal force (up to 0.4 N). The diameter of Myoton 3 testing end was 3 mm and stroke time of testing end of device during all measurements was 15 ms. Previously it has been found that the acquired data of muscle tone, elasticity and stiffness did not depend on the measurer [19] and good reliability of device was noted [4].

Following knee extensor muscles were investigated: *m. rectus femoris (RF), m.vastus medialis (VM)* and *m.vastus lateralis (VL)*. The area for measurements (the middle part of muscle belly) was identified by manual palpation at muscle contraction [9, 18, 7]. The testing end of myotonometer was placed on previously palpated muscle belly. Points for measurements has been marked by marker symmetrically for muscles of right and left body side. Registering tone characteristics of the observable person was in supine position (Figure 1). The muscle tone characteristics were evaluated at rest using MultiScan mode of myotonometer performing 5 measurements in each muscle before and after 8-week HEP. Data were analysed using software Myoton® and mean value from 5 measurements were accepted for future analysis.

Self-reported knee function assessment

Patients assessed their knee joint function using Western Ontario McMaster Universities Osteoarthritis Index (WOMAC) questionnaire which are used for patients with knee joint OA. Questionnaire consists of 24 questions (5 for pain, 2 for stiffness and 17 for physical function of knee joint) [2]. WOMAC index values are in range of 0 (worst) to 100 (best).

Figure 1. Measurement of thigh muscle tone by myotonometer Myoton 3

Statistical analysis

Data are mean and standard deviation (±SD). A paired t-test was used to evaluate differences between pre- and post-HEP session. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

Data of the muscle tone, elasticity and stiffness characteristics are presented in Tables 1, 2 and 3, respectively.

Table 1. Muscle tone characteristics (frequency of muscle oscillation) in women with knee OA before and after 8-week HEP

Muscle	Frequency (Hz)							
	Before HEP				After HEP			
	Mean±SD	Min	Max	Median	Mean±SD	Min	Max	Median
M. rectus femoris								
Affected	11.41±1.46	8.78	13.54	11.58	11.32±1.58	8.56	14.94	11.32
Non-affected	11.56±1.76	8.86	15.06	11.58	11.45±1.94	8.66	15.42	11.48
M.vastus medialis								
Affected	10.31±1.06	8.56	12.04	10.06	10.52±1.25	8.68	12.44	10.32
Non-affected	10.54±1.21	8.76	12.90	10.40	10.48±1.19	8.94	11.7	10.22
M.vastus lateralis								
Affected	11.29±2.75	7.58	17.00	11.24	10.29±1.77*	8.10	14.34	10.12
Non-affected	11.28±2.45	7.40	17.00	11.60	10.68±1.89*	8.60	15.10	10.90

Note: HEP – home exercise program, SD – standard deviation, min-minimum, max-maximum, *p<0.05 as compared pre- and post-HEP

Table 2. Muscle elasticity characteristics (logarithmic decrements) in women with knee OA before and after 8-week HEP

Muscle	Decrement							
	Before HEP				After HEP			
	Mean±SD	Min	Max	Median	Mean±SD	Min	Max	Median
M. rectus femoris								
Affected	1.80±0.32	1.41	2.46	1.77	1.85±0.23	1.44	2.27	1.84
Non-affected	1.69±0.33	1.24	2.23	1.69	1.77±0.22	1.33	2.05	1.81
M.vastus medialis								
Affected	1.33±0.05	1.09	1.52	1.29	1.38±0.22	0.96	1.83	1.34
Non-affected	1.36±0.12	1.14	1.72	1.33	1.32±0.19	0.99	1.75	1.30
M.vastus lateralis								
Affected	1.50±0.27	1.06	2.13	1.49	0.10±0.21	1.23	1.83	1.48
Non-affected	1.51±0.26	1.06	1.93	1.42	1.51±0.22	1.13	1.96	1.41

Note: HEP – home exercise program, SD – standard deviation, min-minimum, max-maximum. Muscle with high elasticity has lower logarithmic value

Table 3. Muscle stiffness characteristics in women with knee OA before and after 8-week HEP

Muscle	Decrement							
	Before HEP				After HEP			
	Mean±SD	Min	Max	Median	Mean±SD	Min	Max	Median
M. rectus femoris								
Affected	192.89±31.17	148.60	255.20	184.40	186.25±33.33	130.20	267.20	191.00
Non-affected	189.48±33.59	145.40	243.20	178.00	186.73±35.86	131.00	259.20	186.60
M.vastus medialis								
Affected	177.52±22.68	146.20	219.80	175.80	179.64±31.66	128.40	238.80	181.20
Non-affected	183.53±29.57	148.00	250.60	180.20	173.72±29.33	127.20	248.00	177.00
M.vastus lateralis								
Affected	178.88±12.47	115.00	261.40	253.60	168.47±34.80*	117.60	250.40	168.00
Non-affected	184.60±6.13	124.60	288.00	183.90	171.07±40.92*	115.00	274.00	175.00

Note: HEP – home exercise program, SD – standard deviation, min-minimum, max-maximum; *p<0.05 as compared pre- and post-HEP

Tone, stiffness and elasticity of *RF* and *VM* muscles did not differ significantly ($p>0.05$) after 8-week HEP as compared to before. Muscle tone and stiffness characteristics of *VL* muscle decreased significantly ($p<0.05$) after 8-week HEP. There was noted no statistically significant difference in muscle tone, stiffness and elasticity between the affected and non-affected leg before and after 8-weeks HEP.

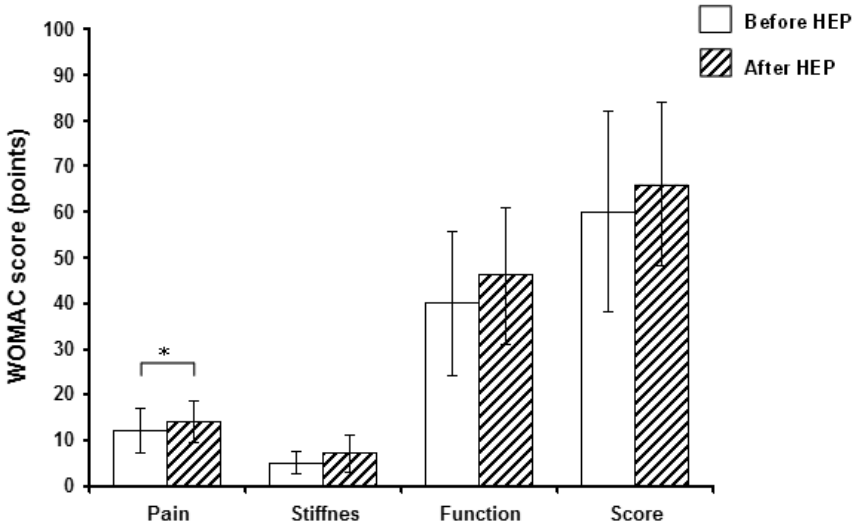

Figure 2. WOMAC index for self-reported assessment of pain, stiffness and function of the knee joint as well as total score in women with knee OA before and after 8-week HEP. Higher score indicates better condition of the knee joint. (mean±SD), *$p<0.05$

In the present study a statistically significant decrease ($p<0.05$) of knee joint pain was noted after 8-weeks HEP, whereas there was no changes in the total score of WOMAC index (Figure 2).

DISCUSSION

The reference values of muscle tone, stiffness and elasticity are individually specific, varying remarkably between test subjects and between muscles [18, 19]. Therefore it is recommended to follow reference values when evaluating the results, also trends of parameters (changes in time) should be considered. Variability of a characteristic is very informative in a longitudinal study [18]. In the present study range of different characteristics was found. Taking all of the results in to calculation both before and after 8-week HEP, the range of

frequency of muscle oscillation were: for *RF* muscle 11.4–15.06 Hz, *VM* muscle 8.56–12.9 Hz, *VL* muscle 7.4–17 Hz. Reference value of frequency of muscle oscillation of non-pathological muscles is 11–16 Hz [18]. When comparing the results of the present study with the reference value of frequency of muscle oscillation it was noted that all measurements of muscle tone characteristics were within the reference value range.

In the present study the ranges of logarithmic decrements for *RF* muscle were 1.24–2.46 (mean 1.78), for *VM* muscle 0.96–1.83 (mean 1.35), for *VL* muscle 1.06–2.13 (mean 1.49). Reference values of logarithmic decrements are below 1.0–1.2 [18]. Lower logarithmic decrement values demonstrate higher elasticity of muscle. It can be concluded that in present study the elasticity of muscles of OA patients was lower as compared to healthy subjects' reference data.

Values of muscle stiffness for *RF* muscle in OA patients were 130–267 N/m (mean 189 N/m), for *VM* muscle 127–251 N/m (mean 179 N/m), for *VL* muscle 115–288 N/m (mean 176 N/m). The range of muscle stiffness reference value is 150–300 N/m [18]. Unfortunately there were no similar studies in the literature for the comparison of changes in muscle tone characteristics after 8-week HEP in women with knee OA. In a recent study by Aird and colleagues [1] no statistically significant difference between mechanical properties (tone, elasticity and stiffness) of *m. quadriceps femoris* in the dominant and non-dominant leg was found in healthy male subjects measured by MyotonPRO myotonometer (Myoton AS, Estonia).

We can conclude that after 8-week HEP patients with knee joint OA had significant decrease of muscle tone and stiffness in *m. vastus lateralis* affected and non-affected thigh. There was noted no significant difference in measured characteristics of other studied muscles of neither affected nor non-affected leg. The measured characteristics also did not differ significantly between legs. It could be proposed that osteoarthritic changes are presented in patients knee joints bilaterally, but in different levels. As a result of 8-week HEP, pain intensity in knee joint decreased, whereas self-reported function of knee joint did not improve significantly. Similar results of the WOMAC index score have also been found by previous studies with patients with knee OA [20]. Preoperative performance of HEP is recommended for improvement of surrounding knee joint muscle function. Future study should be carried out to elucidate which kind of exercise influence the increase of muscle function in knee joint OA patients before TKA with aim to accelerate postoperative recovery.

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