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ORIGINAL RESEARCH

Quadriceps strengthening by the Kaatsu Training method in women with patellofemoral pain

Fortalecimento do quadríceps através do método Kaatsu Training *em mulheres com dor femoropatelar*

Fortalecimiento del cuádriceps con el método kaatsu training *en mujeres con dolor patelofemoral*

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ABSTRACT | This is a cross-sectional, comparative, and randomized study aimed to evaluate the effects of the partial vascular occlusion technique (Kaatsu Training) associated with low load exercises in the muscle strengthening of quadriceps in women with patellofemoral pain. We evaluated 18 women with patellofemoral pain, aged from 18 to 35 years, allocated into two groups. The experimental group performed the strengthening with blood flow reduction with the aid of a sphygmomanometer, associated with low load (≅20% RM). Whereas the control group performed exercises with the same load, but without blood flow reduction. The treatment was performed three times a week for six weeks, totaling 18 sessions. We used the numerical pain rating scale (NPRS) and the anterior knee pain scale (AKPS) questionnaire for evaluation; we evaluated the muscle strength of knee extensors by the digital dynamometer. The results showed that the partial vascular occlusion technique significantly improved the values of quadriceps strength gain in the right, 6.22kg (p=0.03) and left limb, 6.98kg (p=0.04), in women with patellofemoral pain. Therefore, training with partial vascular occlusion can be useful for strengthening of the knee extensor musculature in women with patellofemoral pain who, because of the pain, have low tolerance to high load exercises for muscle strengthening. An effective, safe and cost-effective technique, which does not require an investment in a leg extension machine, since, with a cuff, low load exercises can offer significant results.

Keywords | Knee; Pain; Physical Endurance; Rehabilitation.

RESUMO | Este é um estudo transversal, comparativo e randomizado, cujo objetivo foi avaliar os efeitos da técnica de oclusão vascular parcial (*Kaatsu Training*) associada a exercícios de baixa carga no fortalecimento muscular de quadríceps em mulheres com dor femoropatelar. Foram avaliadas 18 mulheres com dor femoropatelar, com idade entre 18 e 35 anos, que foram alocadas em dois grupos. O grupo experimental realizou fortalecimento com redução do fluxo sanguíneo por meio de um esfigmomanômetro, associado com baixa carga (≅20% RM). Enquanto o grupo-controle realizou exercícios com a mesma carga, porém sem redução do fluxo sanguíneo. O tratamento foi realizado três vezes na semana, em um período de seis semanas, totalizando 18 sessões. Para avaliação foram utilizadas a escala numérica de avaliação da dor (NPRS) e o questionário *anterior knee pain scale* (AKPS); a força muscular de extensores do joelho foi avaliada através do dinamômetro digital. Os resultados mostraram que a técnica de oclusão vascular parcial provocou melhorias significativas nos valores de ganho de força do quadríceps no membro direito, 6,22kg (p=0,03), e esquerdo, 6,98kg (p=0,04), em mulheres com dor femoropatelar. Portanto, treinamento com oclusão vascular parcial pode ser uma alternativa útil para ganho de força da musculatura extensora do joelho em mulheres com dor femoropatelar que, devido à dor, tenham baixa tolerância a exercícios de alta carga para fortalecimento muscular, sendo uma técnica eficaz, segura e com boa relação de custo-benefício, não necessitando a compra de uma cadeira extensora, uma vez que utilizando um manguito é possível obter resultados significativos associados a exercícios de baixa carga

Descritores | Joelho; Dor; Resistência Física; Reabilitação.

RESUMEN | Se trata de un estudio transversal, comparativo y aleatorizado. El objetivo de este estudio fue analizar los

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efectos de la técnica de oclusión vascular parcial (*kaatsu training*) asociada a ejercicios de baja carga en el fortalecimiento del músculo cuádriceps de mujeres con dolor patelofemoral. Participaron dieciocho mujeres con dolor patelofemoral, con edades entre 18 y 35 años, las cuales fueron divididas en dos grupos. El grupo experimental realizó fortalecimiento con restricción del flujo sanguíneo mediante un esfigmomanómetro asociado a baja carga (≅20% RM). Mientras tanto el grupo control realizó ejercicios con la misma carga, pero sin restricción del flujo sanguíneo. El tratamiento se aplicó tres veces por semana, durante seis semanas, en total fueron 18 sesiones. Para la evaluación se utilizaron la escala numérica de calificación del dolor (NPRS) y la *anterior knee pain scale* (AKPS); para estimar la fuerza muscular de los extensores de la rodilla se aplicó el dinamómetro digital. Los resultados mostraron que la técnica de oclusión vascular parcial resultó en mejoras significativas en los valores de ganancia de fuerza del cuádriceps en el miembro derecho, 6,22kg (P=0,03), e izquierdo, 6,98kg (P=0,04), en mujeres con dolor patelofemoral. Por lo tanto, el entrenamiento con oclusión vascular parcial puede ser una alternativa útil para ganar fuerza en los músculos extensores de la rodilla en mujeres con dolor patelofemoral que, debido al dolor, tienen baja tolerancia a los ejercicios de alta carga para el fortalecimiento muscular, lo que muestra ser una técnica eficaz, segura y con buen costo-beneficio, y no necesita para esto la compra de una silla extensible, ya que con un manguito es posible obtener resultados significativos asociados con ejercicios de baja carga.

Palabras clave | Rodilla; Dolor; Resistencia Física; Rehabilitación.

INTRODUCTION

Anterior knee pain is a patellofemoral pain (PFD), and its main characteristic for an assertive diagnosis is the pain around or behind the patella, specifically during activities that have a greater overload in the knee joint during flexion, such as in squatting, climbing/descending stairs, and running[1]. Many biomechanical factors can lead to a PFD, among them: abnormal patellar alignment, trochlear morphology, and quadriceps weakness[1]. This condition affects about 20% of the general population, especially women, and 28.9% of athletic and sedentary adolescents annually[2].

Specific exercises for quadriceps strength gain can be found in protocols for PFD. The American College of Sports Medicine[3] recommends 60 to 70% one repetition maximum (1RM) for strength gain and 70 to 85% 1RM for muscle hypertrophy. These high loads may lead to greater joint overload and worsen pain symptoms in patients with PFD[4].

Kaatsu Training is an exercise-associated blood flow restriction training that uses partial vascular occlusion by blood flow restriction with reduced load (20 to 40% 1RM), without generating joint overload. It helps patients who have musculoskeletal dysfunctions, which can compromise the joint and weaken the adjacent musculature[5].

The exercise of blood flow restriction with low loads (20 to 40% 1RM) may be a safe tool[6] and effective to improve morphology and strength response in human muscle tissue[7]. This restriction generates a local tissue hypoxemia that accelerates glycogen expenditure, making the medium acidic, activating the hypothalamus and increasing GH production, the growth hormone. However, partial occlusion blocks myostatin, a protein that reduces muscle mass, which lead to a greater activation of type IIb muscle fibers (fast and anaerobic fibers) that aid in strength gain[8].

A study using blood flow restriction training in patients with patellofemoral pain showed that the experimental group and the control group had similar strength gain. However, the control group trained with high load (70% 1RM), while the experimental group with low load (30% 1RM)[4]. In our study, the technique, with exercises for strength training with low load, was used in the experimental group and in the control group to detect the effect of partial vascular occlusion.

Therefore, we aimed to analyze the effects of the Kaatsu Training method, performed by partial vascular occlusion, associated with low load training in women with PFD.

METHODOLOGY

This is a cross-sectional, comparative, and randomized study, with double-blind evaluator and quantitative approach, conducted at the Centro Universitário Unisep (CEUUN), in Francisco Beltrão (PR), from August, 17 to October 9, 2020. The initial and final evaluations were performed by two students, while the treatment of the interventions was developed by the study authors. The evaluators were unaware of the participants allocation

to the two groups. The study included 18 women affected by PFD, aged 18–35 years old. After selection, the participants were randomly divided by a lottery method, in which their names were written on small papers and placed inside a container, being drawn and organized into two groups. The treatment protocol with partial vascular occlusion was applied in the experimental group, and the occlusion was not performed in the control group.

Inclusion criteria were: women aged from 18 to 35 years; pain in the anterior region of the knee; and identified by the anterior knee pain scale (AKPS) questionnaire[9]. Exclusion criteria were: having other knee-related pathologies; have varicose veins or cardiovascular problems; have undergone physical therapy in the last two months; and be pregnant.

Initially, each participant filled out the evaluation form and anthropometric data. Subsequently, the knee extensor musculature was bilaterally evaluated by 1RM, 20% bilateral 1RM, and systolic blood pressure (SBP) at rest.

Then, the numerical pain rating scale and the AKPS questionnaire were applied. The AKPS result is a score ranging from 0 to 100, in which 100 means fit to practice physical exercises and 0 indicates a leave from daily activities. A score below 82 indicates a tendency towards patellofemoral disorders[10].

The muscle strength of the knee extensors was quantified with the aid of a portable digital dynamometer (E-lastic) that, by a cell phone application with the activation of Bluetooth and GPS, show data in graphs that quantify the strength of the knee extensor musculature in kilos (kg). All participants were seated to perform this test, with hip flexion at 90° and knee flexion at approximately 70°, a position that shows the peak torque of the knee extensor[11].

The treatment was conducted in a leg extension machine. A device from the Movement brand, model W2, was used to perform strength exercises for knee extensor muscle, three times a week for six weeks, a totaling 18 interventions.

The experimental group was subjected to a muscle strength training with low load, approximately 20% 1RM. It was impossible to work with this exact load due to the limitation of the device, however, the load closer to 20% was used, with only one resistance bar of the equipment that weighed approximately 6.80kg of external resistance. Associated with the load, partial vascular occlusion was performed a with 15cm wide sphygmomanometer, Solidor brand, attached to the proximal region of the unilateral thigh, with insufflation pressure of 20mmHg + SBP at rest[12], and a mean SBP of 123.33mmHg of the experimental group was obtained. Alternate exercises were performed in an open kinetic chain in the leg extension machine to recruit and to activate the quadriceps muscle group in four sets. The first set consisted of 30 repetitions and the other three of 15 repetitions, with intervals of 20 seconds between each set, without deflating the cuff[13]. The control group underwent the same protocol with the same load of 6.80kg of the experimental group, without partial vascular occlusion and performing only a conservative exercise.

Statistical analysis

The numerical variables were evaluated regarding the distribution of normality by the Shapiro-Wilk test and, if the assumption of normality was accepted, they were presented in mean ($\overline{x}$) and standard deviation (SD). The Student's t-test was used for unpaired samples to compare the differences between the means of the groups, with 5% significance level.

RESULTS

Out of 18 participants who started the program, three did not complete the follow-up (two in the control group and one in the experimental group). Table 1 shows the anthropometric data.

We found no statistically significant difference between the groups after the initial evaluation (Table 2).

The comparison between the groups after the final evaluation showed a statistically significant difference regarding the maximum resistance of the right and left knees extensor musculature, with higher mean strength for the experimental group (Table 3).

Table 1. Sample characterization, mean (standard deviation)

	Control group (n=7) $\overline{X}$ (SD)	Experimental group (n=8) $\overline{X}$ (SD)
Age (years)	28.5 (3.90)	23.2 (1.98)
Weight (kg)	60.6 (12.17)	58 (6.44)
Height (m)	1.59 (0.03)	1.62 (0.06)
BMI	23.7 (4.68)	22 (2.05)
Systolic Blood Pressure/ Rest (mmHg)	114.3 (13.97)	122.5 (7.07)

$\overline{X}$ (SD): mean (standard deviation); BMI: body mass index.

Table 2. Comparison of the initial values of bilateral quadriceps strength

Characteristic	Control Group $\overline{X}$ (SD)	Experimental Group $\overline{X}$ (SD)	T	p
RM_R_Initial	37.42 (8.16)	39.47 (5.46)	−0.57	0.57
RM_L_Initial	38.65 (5.34)	39.72 (7.58)	−0.31	0.76
20%_RM_R_Initial	7.48 (1.63)	8.20 (1.55)	−0.86	0.40
20%_RM_L_Initial	7.73 (1.06)	7.94 (1.51)	−0.31	0.76
Score_AKPS_Initial	79.85 (13.92)	77.75 (11.53)	0.32	0.75
Pain_NPRS_Initial	6.71 (1.11)	6.12 (0.64)	1.27	0.23

$\overline{X}$(SD): mean (standard deviation); RM_R_Initial: initial maximum resistance of the right knee quadriceps; RM_L_Initial: initial maximum resistance of the left knee quadriceps; Score_AKPS_Initial: initial score of the anterior knee pain scale questionnaire; Pain_NPRS_Initial: initial value of the numerical pain rating scale.
*Student's t test (p≤0.05): statistically significant difference.

Table 3. Comparison of the final strength values of the bilateral quadriceps

Characteristic	Control Group $\overline{X}$ (SD)	Experimental Group $\overline{X}$ (SD)	T	p
RM_R_Final	39.28 (7.78)	47.57 (5.50)	−2.40	**0.03***
RM_L_Final	40.20 (6.63)	48.25 (7.16)	−2.28	**0.04***
Score_AKPS_Final	90.28 (6.04)	90.87 (6.08)	−0.18	0.85
Pain_NPRS_Final	3.28 (1.11)	1.87 (1.55)	1.99	0.06

$\overline{X}$(SD): mean (standard deviation); RM_R_Final: final maximum resistance of the right knee musculature; RM_L_Final: final maximum resistance of the left knee musculature; Score_AKPS_Final: final score of the anterior knee pain scale questionnaire; Pain_NPRS_Final: final value of the numerical pain rating scale.
*Student's t test (p≤0.05): statistically significant difference.

The experimental group significantly improved the strength value of the left knee extensor musculature when comparing the values of the initial and final evaluation (Figure 1). After the intervention, participants improved their score from 39.72kg in the initial evaluation to 48.25kg in the final evaluation.

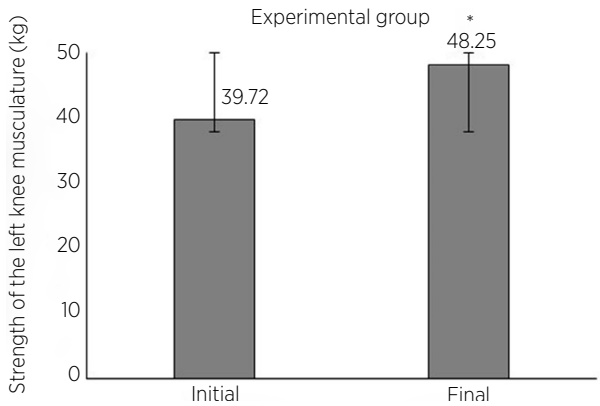

Figure 1. Comparison between means of final muscle strength of a maximum repetition of the left knee extensors
*Student's t test (p≤0.05): statistically significant difference.

The experimental group significantly increased the strength value of the right knee musculature when comparing the values of the initial and final evaluation (Figure 2). The participants increased from 39.47kg in the initial evaluation to 47.57kg in the final evaluation after the intervention.

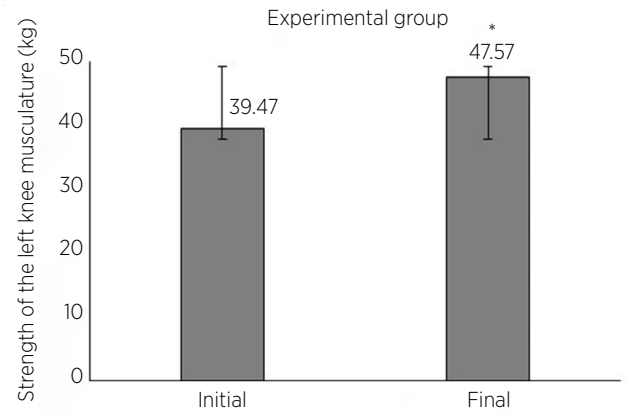

Figure 2. Comparison between means of final muscle strength of a maximum repetition of the right quadriceps

For the AKPS questionnaire, there were no significant differences between the groups.

DISCUSSION

The low-load flow restriction method significantly increased strength gain in the knee extensor musculature in women with PFD when comparing the results of both groups. Strength gain is essential, since conservative treatment of PFD usually focus on quadriceps strengthening. This management is based on the idea that the quadriceps is responsible

for the dynamic stabilization of the patella within the trochlear groove[14].

Studies on the results of quadriceps strength training (ranging from four to six weeks) showed gains of 5–25%[15,16]. Results similar to our study, in which the experimental group showed 21% gain in the left limb and 20.5% in the right limb. Generally, high intensity endurance exercises (approximately 80% 1RM) are ideal to increase muscle size and strength. However, many patients with knee injuries report discomfort when performing conventional exercises for muscle strength gains with high load. In this context, low intensity endurance exercises (20% 1RM) are combined with vascular occlusion to increase muscle strength.

Giles et al.[4] showed a protocol consisting of low load exercises associated with blood flow restriction in patients with PFD (n=69). The participants of this study were divided into two groups: control group (70% 1RM), without occlusion, and experimental group (30% 1RM), with occlusion. Both groups performed exercises on the leg extension machine and leg press. Both groups showed similar increase in strength, although the experimental group showed better results regarding pain reduction.

Some authors have shown that partial vascular occlusion associated with low load exercises can increase muscle strength due to a higher activation of fast contraction fibers (type II)[17,18]. Partial occlusion generates an anaerobic environment in the muscular belly, anticipating the activation of type II fibers, with greater predominance of strength, thus decreasing the activation of slow contraction fibers (type I)[5,18]. Other authors have hypothesized that the effects of partial vascular occlusion are related to increased secretion of the growth hormone and activation of the protein synthesis mechanism[19]. Studies show that training with low load and blood flow restriction (30% 1RM) showed the same results in functional muscle adaptations compared to high load training (75% 1RM)[18,20]. However, endurance exercises with low vascular occlusion pressure may be potentially useful for increased strength[21].

Our study shows that pain, measured by the numerical pain rating scale[22], changed in both groups from moderate in the initial evaluation to mild in the final evaluation. Pain reduction as a consequence of muscle strength training occurs because the knee joint muscles prevent lateral sliding of the patella and the increase of the joint contact area, which decreases joint overload and, consequently, reduces pain[23]. However, a greater sample size would provide more expressive and significant results on pain reduction.

A systematic review based on clinical trials showed that strength training of hip and knee muscles, three times a week for six weeks, can reduce pain and improve functioning in people with very high levels of patellofemoral pain[24]. The analysis of the results of the AKPS questionnaire showed that the participants left the status "with a tendency to patellofemoral disorders" to the level "fit to perform physical activities."

We also emphasize the minimum detectable change (MDC) because a study showed that MDC is 14 for the AKPS, which means that a variation of 14 points or more is necessary to reflect the real change in the patient's condition[25]. We observed that the experimental group increased 13.12 points, a value close to detect a real change.

Our study has some limitations. Firstly, we could not use the exact 20% 1RM load, due to the limitation of the leg extension machine with the external load imposed by the machine, using a fixed load of 6.80kg, equivalent to the weight of the resistance bar of the equipment. The load used for both studied groups was close to 20% 1RM. Besides, we emphasize that the treatment was performed in a short period and with a smaller number of participants, due to the COVID-19 pandemic.

Another possible bias of the study relates to one of the main problems of a cross-sectional study: reverse causality. Since, regarding the variable muscle strength, we cannot confirm if its loss was a cause or consequence of PFD, depending on the patient's clinical and/or functional condition. Future studies must include larger samples and partial vascular occlusion intervention to evaluate any placebo effect.

CONCLUSION

Training with partial vascular occlusion may be a good alternative for strength gain of the knee extensor musculature in women with PFD who, due to pain, have low tolerance to high load exercises for muscle strengthening. Because the technique enables to obtain strength gain with low loads with the Kaatsu Training method.

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