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Comparison of contraction intensity and perceived intensity between dominant and non-dominant leg in sedentary adults

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Abstract

Introduction. Accurate measurement of isometric contraction intensity is a prerequisite for establishing an exercise program and developing a rehabilitation plan. Despite numerous studies performed previously, there is no research on sedentary populations susceptible to injury during exercise. Additionally, although dominant and non-dominant legs showed differences in muscle properties, the legs were not separately investigated. The purposes of this study were to compare the contraction intensity with target intensity and with perceived intensity across 3 different target intensities in sedentary adults and examine the difference between the dominant and non-dominant leg.

Methods. Voluntary isometric contractions were performed with resistance provided by a sling rope and measured with a strain gauge during hip extension. First, maximum voluntary contraction (MVC) was executed; subsequently, submaximal contractions at target intensities (75%, 50%, and 25% of MVC) were randomly performed. Perceived intensity was measured at each target intensity.

Results. Hip extension forces were significantly different across the 3 intensities ($p < 0.001$), with no significant difference between target intensity and contraction intensity or between perceived intensity and contraction intensity. There was no significant difference between the dominant and non-dominant leg. Bland-Altman analysis of the agreement between perceived and contraction intensities revealed a proportional bias for the values within each target intensity (mean bias: –1.15%, standard deviation of bias: 20.96).

Conclusions. Sedentary subjects were able to distinguish 3 different contraction intensities. Perceived intensity could statistically significantly predict contraction intensity. However, clinicians should note that under- or overestimation can occur regardless of the level of target intensity.

Key words: hamstring muscles, isometric contraction, muscle stretching exercises, sedentary behaviour

Introduction

To establish a strategy for an effective increase in extensibility of the muscle-tendon unit, accurate measurement of isometric contraction intensity must be performed before applying a stretching regimen. Various methods and instruments have been proposed to quantitatively measure the intensity of proprioceptive neuromuscular facilitation (PNF) stretching, which utilizes a voluntary isometric contraction [1, 2]. However, unlike in the laboratory, it is difficult to use specialized equipment in the sports field or in the clinic owing to the spatial constraints and the additional time required to prepare and operate the equipment. Alternatively, rating of perceived exertion (RPE) is widely used in most cases. Briefly, physical therapists or athletic trainers set specific stretching intensity depending on the target and require the subject to perform muscle contraction on the basis of the proposed intensity. Then, the subject quantifies the perceived exertion after a set of voluntary isometric contractions. However, it is not known how accurately the individual performs the given intensity and how accurately they are aware of the contraction intensity.

Various studies have demonstrated the effects of PNF stretching on flexibility with different contraction intensities [3–5]. However, previous research provided torque or force values in real time, allowing subjects to identify their contraction intensity values. It is problematic to apply the experimental results obtained in laboratory settings to sports field or clinical settings because of the difficulty to accurately estimate how much the subject performs the activity with the intensity requested by clinicians under actual field conditions. It is necessary to confirm whether the participants discern and perform the intensity suggested by the clinicians without visual biofeedback. A previous study was conducted in young and healthy field sport athletes. In the experiment, it was possible to distinguish 100%, 50%, and 20% of maximum voluntary contraction (MVC) while performing PNF stretching [6]. However, there have been no studies among sedentary populations with a high risk of injuries due to low muscle strength and bone mineral density [7]. The number of people who participate in sports has been increasing with the increasing interest in health, living standards, and education levels [8]. Nevertheless, most of the studies on stretching intensity have been mainly focused on professional athletes or patients that were already injured and thus an investigation of sedentary subjects is currently required. Even in young college students, sedentary behaviour has been shown to negatively affect bone and muscle qualities [9, 10].

Perceived exertion is defined as 'the subjective intensity of effort that is felt during physical exercise' [11, p. 407]. The study of perceived exertion is clinically significant because equipment to quantitatively measure contraction in-

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tensity is not always available in the clinical practice. Previous studies demonstrated the relationships of RPE with metabolic stress and lactate concentration during aerobic exercise, showing the usefulness of RPE for exercise monitoring [12]. Other research has shown that RPE is associated with cerebral activity in addition to physiological properties [13]. With the same contraction intensity, RPE values may vary with duration and repetition [14]. However, RPE poses several potential problems. Reported RPE values may include additional information, such as discomfort and muscle pain, not just the intensity of the exercise [15]. Additionally, most of the existing studies were conducted with the use of Borg's category-ratio scale (CR-10). CR-10 is easy to understand and apply, while the range of 0–10 makes it difficult to compare with the range of 0–100 in terms of percentage. Moreover, the range limited to 0–10 is difficult to sufficiently reflect information about the subjects, so loss of some information may occur in the recording step. Another limitation of previous studies is that those concerning different stretching intensity settings were focused on one leg, without specifying which leg it was. Dominant and non-dominant legs show differences in flexibility and architectural characteristics, as well as muscle strength [16]. In addition, the asymmetry of these 2 legs may lead to differences in the risk of damage [17].

The purposes of this study were to (1) compare the contraction intensities across 3 different target intensities and examine the difference between the dominant and non-dominant leg and (2) compare contraction intensity with target intensity and with perceived intensity in healthy sedentary subjects.

Subjects and methods

Subjects

Overall, 31 participants who presented sedentary lifestyles were recruited for this study (age: 22.1 ± 1.6 years, weight: 61.0 ± 12.1 kg, height: 165.1 ± 8.4 cm). They were defined as sedentary if they did not meet the physical activity recommendations of the American College of Sports Medicine and American Heart Association and undertook 'any working behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalents while in a sitting or reclining posture' [18, 19, p. 540]. Individuals with a history of surgery or hip, knee, or ankle joint pain within the previous 6 months were excluded.

Procedures

The leg dominance of the subjects was confirmed before the experiment, and the experiment order was determined randomly. When the participants lay in the supine position on a treatment table, the examiner slowly lifted the designated leg using a sling system (Marpe Inc., Jeonju, Korea) until the individuals felt pain or discomfort. After fixing the sling rope in the end range, one end of the rope was securely attached to the ceiling and the other end was connected to the ankle strap. The subjects then performed maximum hip extension. The examiner placed their hands on both sides of the ankle joint to prevent unnecessary motion of the legs in the transverse plane during hip extension. Voluntary isometric contractions were performed with the resistance provided by the sling rope during hip extension. This followed the general procedure for contract-relax PNF stretching, except that the resistance generated during the isometric contraction was caused by the fixed rope instead of a practitioner [4]. The forces generated by hip extension during MVC were measured with a strain gauge (Re-live Inc., Gimhae, Korea). MVC was performed in a total of 3 trials (6 s/trial, 5-s rest between the trials), and the mean value was used for the analysis. After 3 minutes of rest, submaximal contractions were performed. The target intensities for the submaximal contractions were 75%, 50%, and 25% of MVC and were applied randomly. During the submaximal contractions, the examiner instructed the participants to remember the maximum intensity contraction that they performed in the previous step and to execute a voluntary isometric contraction at 75% (or 50% and 25%) of MVC. As in MVC, a total of 3 trials (6 s/trial, 5-s rest between the trials) were performed in each submaximal contraction, and the mean value was used for the analysis. Contraction intensity (%MVC) was calculated by dividing the mean of the absolute values measured in each submaximal contraction by the mean of the absolute values measured in MVC and multiplying by 100. When the measurement was completed at one target intensity, before proceeding to the next target intensity, the examiner asked the participants what percentage of the contraction intensity they exerted relative to MVC and recorded the value as perceived intensity (%MVC). After all measurements at the 3 different target intensities were completed, the submaximal contraction force was measured with the same procedure on the opposite leg in the same position and was calculated as %MVC. Perceived intensity was also confirmed and recorded after completion of measurement at each target intensity. The hip extension forces displayed in real time on the strain gauge during hip extension were blinded to the participants.

Data analysis

The Shapiro-Wilk test was performed to verify the normality of data. A 3-way analysis of variance with a Bonferroni post-hoc test was used to examine the effects of various factors. Linear and quadratic regressions were applied to investigate the relationship between perceived and measured MVC (%). Additionally, a Bland-Altman agreement analysis was conducted to determine the mean bias and limits of agreement. The statistical analyses were performed with the SPSS Statistics 25 software (IBM Corp., Armonk, NY, USA). The threshold for statistical significance was set at $p < 0.05$. Values are reported as mean ± standard deviation (*SD*). The total sample size was calculated with the G*Power version 3.1.9.7 software (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany), with the alpha probability of 0.05 and a power of 0.8.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Institutional Review Board of Woosong University (approval No.: 1041549-191011-SB-81).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

There were no statistically significant interactions. Hamstring extension forces measured by the strain gauge across the 3 different intensities (75%, 50%, and 25% of MVC) were only significantly different ($p < 0.001$) (Table 1). No significant differences between target intensity and contraction intensity (Figure 1) or between perceived intensity and contraction intensity (Figure 2) were observed. In the dominant leg, a linear ($F_{1, 91} = 56.25$, $p < 0.001$) and quadratic ($F_{1, 91} = 27.98$, $p < 0.001$) regression established that perceived intensity could statistically significantly predict contraction intensity, and perceived intensity accounted for 37.7% and 37.6% of the explained variability in contraction intensity, respectively. The regression equations were linear (predicted contraction intensity = 9.151 + 0.833 * perceived intensity) and quadratic (predicted contraction intensity = 4.160 + 1.083 * perceived intensity) (Figure 3). Bland-Altman analyses revealed that the mean bias was –1.15% and *SD* of bias equalled 20.96 (Figure 4). Limits of agreement (bias ± 1.96 *SD*) ranged from –42.69 to 40.37% ($p = 0.599$).

Contraction intensities and perceived intensities were significantly different between 75% and 50%, between 75% and 25%, and between 50% and 25% of MVC.

Table 1. Contraction intensity and perceived intensity across 3 different target intensities

Target intensity		75% of MVC	50% of MVC	25% of MVC
Non-dominant	Contraction	70.2 ± 23.4%	50.9 ± 29.4%	29.4 ± 15.3%
	Perceived	72.0 ± 5.4%	48.9 ± 5.7%	24.0 ± 4.7%
Dominant	Contraction	69.3 ± 23.5%	50.3 ± 21.4%	27.8 ± 16.4%
	Perceived	70.6 ± 6.6%	48.4 ± 6.9%	24.9 ± 5.1%

MVC – maximum voluntary contraction

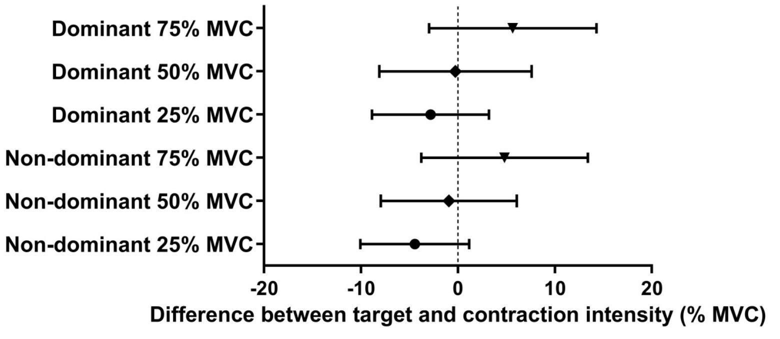

Figure 1. Mean difference between target intensity and contraction intensity and 95% confidence intervals

MVC – maximum voluntary contraction

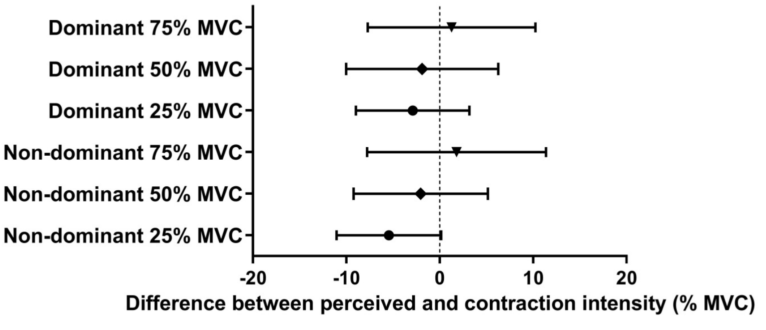

Figure 2. Mean difference between perceived intensity and contraction intensity and 95% confidence intervals

MVC – maximum voluntary contraction

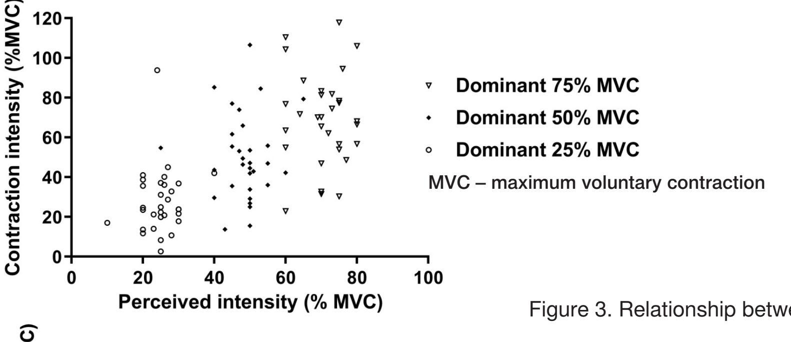

Figure 3. Relationship between contraction intensity and perceived intensity

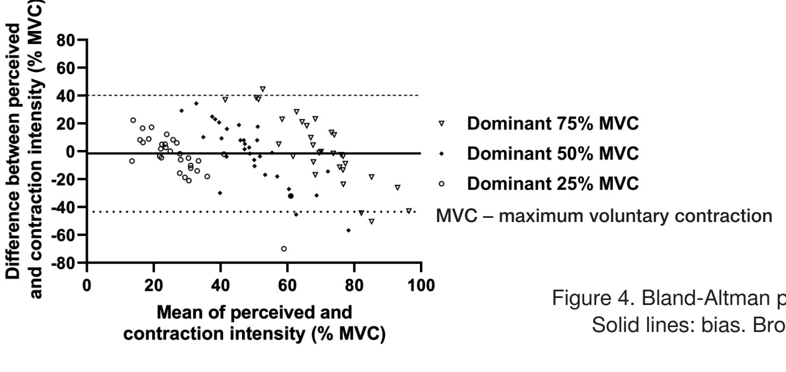

Figure 4. Bland-Altman plot of perceived intensity and contraction intensity. Solid lines: bias. Broken lines: limits of agreement (bias ± 1.96 *SD*)

Discussion

Intensity differentiation and comparison between dominant and non-dominant leg

In this study, the pairwise comparison of contraction intensities measured at 3 different target intensities (75% vs. 50%, 75% vs. 25%, and 50% vs. 25% of MVC) showed significant differences. In other words, the sedentary population participating in the experiment distinguished 25% differences in intensities, which means that they controlled muscle contraction within a certain range. During isometric contraction, motor unit recruitment and rate coding are constantly changing in accordance with the feedback, which helps muscles maintain the assigned contraction intensity [20, 21]. Changes in neuromuscular activation can be identified through electromyography, and increased electromyographic activity is observed in sustained contraction [21]. One characteristic of this experiment is that *SD* and 95% confidence interval gradually increased from low intensity to high intensity. At high intensity, the variation is large, so individual values are widely distributed from the mean. It may be difficult to exactly perform and control muscle contraction at high intensity, depending on the participant. If the scale of target intensities is divided into 10% intervals, there may be significant overlap between 2 adjacent target intensities, especially at higher intensities [22, 23]. The interval of muscle contraction intensity that the human body can distinguish and perform may be estimated to be around 25%. Subdividing the intensity into intervals smaller than 25% may not be worthwhile in clinical practice because it would be difficult to distinguish clearly between 2 adjacent intensities. This may vary depending on age, gender, and degree of muscle development [24, 25]. Interestingly, there was no significant difference between the dominant and non-dominant leg. People use their preferred (dominant) leg to manipulate an object, while they employ their non-preferred (non-dominant) leg for stabilizing and supporting activities [26, 27]. In general, dominant legs show differences in functional properties, such as functional skill and fine motor control, as well as in physical properties, such as muscle strength and endurance beyond high preference and convenience in terms of use [16, 28]. In the case of hands, there was also a difference in cortical activity between dominant and non-dominant ones even in the same motion [29]. This study compared contraction and perceived intensity between the dominant and non-dominant leg, which showed no significant differences. In professional athletes with well-developed muscles through training, there were significant differences in the physiological and physical properties of the muscles between dominant and non-dominant legs, but the differences may have been minor in the sedentary population [30, 31]. Additionally, this experiment was solely focused on voluntary isometric contraction performed at a fixed joint angle; hence, the afferent stimuli may have been low compared with the dynamic activity [32, 33]. Even if there were some differences between legs, the effects of the single factor would decrease owing to complementation of the other factors [34]. It is difficult to judge the proprioceptive capacity of 2 legs only on the basis of this experiment. For an in-depth understanding, it is necessary to conduct further studies among various participants, including athletes with well-developed muscles and patients with muscle damage, during static and dynamic activity.

Difference between target intensity and contraction intensity

There was no significant difference between target intensity and contraction intensity, suggesting that the level of intensity compliance was significantly acceptable at all 3 different intensities. Previous studies reported under-contraction at high intensity and over-contraction at low intensity [6, 35]. Sheard et al. [6] measured voluntary isometric contraction at 3 different target intensities (100%, 50%, and 20% of MVC) in athletes. Under-contraction was observed relative to the target intensity at 100%, and over-contraction was observed relative to the target intensity at 20%. The athletes were expected to more precisely control muscle contraction intensity thanks to well-developed muscles, but in practice they did not. Interestingly, this study confirmed that target intensity and contraction intensity matched significantly in the sedentary population, exhibiting relatively low muscle quality [36, 37]. This may have been due to athletes' having a much wider range of muscle forces compared with the sedentary population. As athletes have more muscle mass and a larger cross-sectional area, the maximum muscle force produced during MVC will be higher [38]. In addition, the maximum intensity in the previous study equalled 100% of MVC, which was higher than the 75% set in this study, and the minimum intensity equalled 20%, which was lower than the 25% set in this study. In other words, the range between high intensity and low intensity was inevitably wider, so it may have been more difficult for the participants to accurately match the contraction intensity to the target intensity. Unlike in previous studies, there was no statistically significant difference between target intensity and contraction intensity at both 75% and 25% of MVC, but the trends were similar to those observed in previous studies. At a high intensity (75% of MVC), under-contraction (69.8 ± 20.7%) was reported, and at a low intensity (25% of MVC), a slight over-contraction (28.6 ± 15.0) was noted. At a moderate intensity (50% of MVC), almost the same value was measured as 50.6 ± 18.3%. Considering previous studies and this study, therapists can expect high-intensity compliance in participants when moderate-intensity PNF stretching is required in clinical practice.

Relationship between perceived intensity and contraction intensity

The correlation between perceived exertion and contraction intensity has been widely demonstrated in several studies. However, most of the previous investigations used CR-10 developed by Borg to measure perceived exertion [22]. This study was performed after precisely matching both the ranges of perceived exertion and contraction intensity from 0 to 100%. There was no significant difference between the measured intensity and the contraction intensity. Regression analysis also showed statistically fit linear and quadratic trends. This means that the participants were accurately representing the contraction intensity they had performed after voluntary isometric contraction. However, even if 2 different measurements had a high correlation, this does not imply a good agreement. Therefore, the relationship between the 2 measurements was further validated by the Bland-Altman analysis. A value greater than 0 in the Y axis means that the perceived intensity was greater than the contraction intensity (overestimation), and a value less than 0 means that the perceived intensity was lower than the contraction intensity (underestimation). In the dominant leg, the underestimate rate was

54.8% at 75% of MVC, 48.4% at 50% of MVC, and 51.6% at 25% of MVC. At 3 different target intensities, the perceived intensity did not appear to exhibit bias in one direction (overestimation or underestimation). However, interpretation of perceived intensity requires some attention. A closer look at the Bland-Altman plot reveals that the values within each target intensity present proportional bias [39]. As the mean of perceived and contraction intensity increased, the perceived intensity tended to gradually underestimate the contraction intensity. This was because the contraction intensity was underestimated when it was high and overestimated when it was low. Previous studies predominately focused on the comparison of the mean intensity differences, and no analysis was performed to investigate the individual intensities [22, 40]. This study shows that underestimated patterns at relatively high intensity and overestimated patterns at relatively low intensity occurred in the same pattern at each target intensity. Secondly, we note that the variation of a set of values in perceived intensity and contraction intensity was significantly different. For example, in the 95% confidence interval of the dominant leg at 75% of MVC, the contraction intensity was wide (60.7%, 78.0%), but the perceived intensity was quite small (68.2%, 73.0%). The perceived intensity was queried verbally after the target intensity was given and recognized. The participants may experience internal psychological resistance when presenting perceived intensities that deviate significantly from the target intensity values specified by the clinician. Taken together, the results in this study demonstrated not only a relationship between perceived intensity and contraction intensity, but also the importance of a separate analysis at each target intensity.

Limitations

The generalizability of these findings to other populations is limited because only young healthy subjects participated in this experiment. Young adults with neuromusculoskeletal injuries or older adults with sarcopenia, characterized by an age-related decline in muscle quantity and quality, might react differently. In addition to expanding such assessments to other groups, investigating muscle activity with electromyography might further understanding of the roles of individual muscles during graded submaximal and maximal contractions. The muscle forces measured in the current study reflect the activities of all hip extensors despite each muscle having different mechanical and physiological properties.

Conclusions

Using quantitative measurement equipment routinely is difficult owing to spatial and temporal limitations in the field of sports and clinical practice. Therefore, therapists or trainers widely use RPE instead. Understanding how a participant perceived and reported values with respect to the actual measured values will be of great help in establishing an exercise program and developing a rehabilitation plan. In particular, sedentary populations are more susceptible to injury during exercise, so more careful management is required. In this study, the subjects were able to distinguish the 3 different contraction intensities and were aware of the intensity they had performed at any given intensity. In addition, no difference was found between the dominant and non-dominant leg. However, the contraction intensity at high intensity was variable and might not allow participants to perform the isometric contraction to the intensity level asked for by the clinician. Clinicians' requirements of 50% of MVC from subjects might be ideal in terms of compliance, safety, and effectiveness, as repetitive high-intensity muscle contraction is likely to cause pain and poses a potential risk of injury. Lastly, regardless of the level of target intensity, it should be noted that actual contraction intensities performed tend to be underestimated when the actual contraction intensity is greater than the target intensity and overestimated when it is lower than the target intensity.

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Disclosure statement

The author does not have any financial interest and did not receive any financial benefit from this research.

Conflict of interest

The author states no conflict of interest.

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