INTRODUCTION

Decreased physical activity is a relevant consequence of social restrictions in response to coronavirus disease (COVID-19) infection.1,2 A study of 455,404 people from 187 countries by Tison et al. that measured daily step count, an indicator of physical activity, reported an average 5.5% reduction in daily steps in the first 10 days, with reductions in days 27.5% within 30 days after COVID-19 pandemic declaration. A study in Singapore reported a 20% reduction in daily steps in the 30 days following the declaration of a COVID-19 pandemic.3 Reducing the number of steps leads to mechanical unloading of the muscles, which leads to a loss of muscle mass and strength.4 Two weeks of inactivity (75% reduction in daily steps) reduce quadriceps muscle strength by up to 8%.5 Inactive and untrained persons may also result in muscle imbalance.6 A study by Pringga showed that hamstring strength is 30-40% lower than quadriceps strength in untrained healthy subjects.7 Hamstring and quadriceps imbalances can affect the dynamic stability of the knee and increase the risk of ACL and hamstring injuries.8 The hamstrings must be able to eccentrically counteract the concentric contraction of the quadriceps during knee extension in order to stabilize the lower body, especially during knee extension. The ability of the hamstrings to provide joint stability during dynamic knee extension can be assessed by calculating the functional hamstring-to-quadriceps ratio (dynamic control ratio).9,10

Resistance training is a proven classic strengthening method that increases muscle mass, strength, and function.1 Another method of resistance training is neuromuscular electrical stimulation (NMES).11 NMES has been used to restore strength and muscle mass after injury or surgery and for long-term sports training to optimize muscle performance.12-14 A hybrid exercise developed at Kurume University in Japan that utilizes the force generated by an electrically stimulated antagonist muscle to provide resistance to a voluntarily contracting agonist muscle. This exercise might be an effective choice for strengthening exercises during a pandemic because it does not require external resistance or stabilization devices. In addition, engaging the eccentric contraction of the antagonist muscle while the agonist is contracting concentrically may reduce agonist-antagonist muscle imbalance and reduce the risk of injury. Because the hybrid training system device was difficult to replicate, modifications were carried out using conventional stimulation tools.

Methods: The research was conducted at the Medical Rehabilitation Installation of Dr. Soetomo General Academic Hospital Surabaya. The research subjects were 24 untrained healthy men aged 18-40 years divided into two groups: the treatment group who received modified hybrid strengthening exercises and the control group who received Russian protocol neuromuscular electrical stimulation (Russian NMES), 3 times per week for 4 weeks. Statistical tests were carried out on 12 treatment group subjects and 12 control group subjects who were able to complete the study.

Results: There was a decrease in non-dominant 60°/sec DCR (p-value 0.002) and non-dominant 120°/sec DCR (p-value 0.019) in the treatment group. There was no significant difference in 60°/sec and 120°/sec DCR on both sides of the leg in the control group. There is a significant difference in ΔDCR between the two groups at non-dominant DCR 120°/sec (p-value 0.036).

Conclusion: There was a greater reduction of knee joint DCR in the modified hybrid resistance training compared to the Russian NMES in untrained healthy subjects.
compared to conventional strength training. A study by Ito in 2004 using healthy male volunteers reported an increase of maximal volitional contraction of the knee flexor extensors by 3.4% and knee flexor extensor muscle mass of 5.3% after hybrid strengthening exercises three times per week for 4 weeks. Study by Iwasaki using healthy men reported that muscle strength is increased in concentric torsion of the quadriceps at angular velocities of 30°/s and 180°/s, respectively 22% and 26% after hybrid strengthening exercise 3 times/week for 3 weeks. Continuing hybrid strengthening exercises up to 6 weeks resulted in increases in quadriceps concentric torque of 28% and 33% at angular velocities of 30°/s and 180°/s, respectively.

Strengthening exercises using this hybrid approach can be an effective option for reducing agonist-antagonist imbalances because they involve eccentric contractions of the antagonist muscles as well as concentric contractions of the agonist muscles. Research about hybrid strengthening exercises is currently limited because hybrid training systems cannot be easily replicated, and no studies have reported the effect of using hybrid strengthening exercises on the dynamic control ratio, a parameter of agonist-antagonist muscular balance. The purpose of this study was to investigate the effect of hybrid strengthening exercise on quadriceps muscle with modifications using conventional stimulation tools on the dynamic control ratio of the knee joint, compared to Russian NMES training.

**METHOD**

This is an experimental study carried out at the Medical Rehabilitation Installation of Dr. Soetomo General Academic Hospital, Surabaya, using a randomized controlled trial with pre-and post-test designs. The study was conducted between November 2022 and December 2022.

These are the criteria for inclusion: 1) healthy, untrained men who have not participated in a lower leg muscle strengthening exercise program with a certain intensity regularly (minimum 2x/week) in the past 6 months, 2) between the ages of 18 and 40, 3) a low or moderate level of physical activity as measured by the International Physical Activity Questionnaire-Short Form (IPAQ-SF) questionnaire, 4) normal musculoskeletal function (strength, sensation, and normal joint range of motion), and 5) willingness to become a research subject and participate in the entire series of research by signing informed consent. This study's exclusion criteria are as follows: 1) are unable to exercise (joint or muscle pain during active movement, acute knee joint inflammation), 2) are unable to receive neuromuscular electrical stimulation (pacemaker use, allergy to stimulation electrodes), 3) have sustained an injury to the knee joint and the soft tissue surrounding it in the lower leg within the past three months, and 4) have performed muscle-strengthening exercises within the past six months.

All research subjects who met the inclusion criteria were included in the study until the desired number of subjects was reached through consecutive sampling. Using simple randomization with a sealed envelope, the subjects were randomly assigned to a treatment group and a control group.

Prior to intervention, all subjects will have their dynamic control ratio (DCR) of the knee joints measured using the ratio of the peak eccentric torque of the hamstring (Hecc) to the peak concentric torque of the quadriceps femoris (Qcon) from an isokinetic strength test at angulation speeds of 60°/sec and 120°/sec.

To train the quadriceps muscles, the treatment group did modified hybrid strengthening exercises that used voluntary quadriceps contraction against electrically stimulated hamstring contraction. Neuromuscular electrical stimulation of the quadriceps muscle was administered to the control group. Each session in both groups consisted of 10 sets with 10 repetitions and a one-minute break between sets. Each group receives 12 sessions, three sessions per week for four weeks. Both legs were targeted by the intervention.

The same stimulation parameters were used by both groups: A carrier with a frequency of 5000 Hz that is modulated at a frequency of 20 Hz (2.4 ms on, 47.6 ms off) is used in Russian stimulation. At the beginning of each exercise, the intensity will be adjusted to 80 percent of the maximum comfortable intensity. The patient's dynamic control ratio of the knee joint will be measured once more after four weeks (12 sessions of exercise).

SPSS version 26 was used to conduct a statistical analysis of the collected data. The Monte Carlo test was used to test for data normality. The Levene test was used to examine the homogeneity of the data. When the data were not normally distributed, the Wilcoxon Signed Rank test or the paired t-test were used to compare DCR values before and after treatment in each group. In the event that the data were not normally distributed, the Mann-Whitney test or independent t-test was used to compare the DCR values that were different before and after treatment. If P < 0.05, the p-value is considered significant. Cohen's d test was used to measure effect size.

**RESULTS**

This study included 24 individuals, 12 of whom were enrolled in each of the two groups—treatment and control. All participants in the treatment and control groups were able to finish the study until the end. In either group, no adverse effects were found. At the start and end of the study, statistical tests were performed. In the control group, the average age of the participants was 32.42 ± 4.01 years, while the average age of the treatment group participants was 30.67 ± 1.88 years. The treatment group had an average weight of 74.17 ± 9.02 kg, while the control group had an average weight of 75.75 ± 11.96 kg. The treatment group had an average height of 1.70 ± 0.07 m, while the control group had an average height of 1.70 ± 0.07 m. The treatment group had an average BMI of 25.68 ± 3.78 kg/m², while the control group had an average BMI of 26.18 ± 3.42 kg/m². The distribution of all baseline data was normal. The Levene test revealed that the age data for the two groups were not homogenous, but additional statistical tests using the independent sample t-test demonstrated that there was no statistically significant age difference between the two groups (P-value 0.190). The characteristic of the subject is shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
</table>

By comparing knee joint DCR values before and after four weeks of exercise,
Table 1. Characteristic of subjects

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Treatment (n = 12)</th>
<th>Control (n = 12)</th>
<th>p-value</th>
<th>p-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means ± SD</td>
<td>(Normality)</td>
<td>Means ± SD</td>
<td>(Normality)</td>
<td>Homogeneity</td>
</tr>
<tr>
<td>Age (years)</td>
<td>30.67 ± 1.88</td>
<td>0.490</td>
<td>32.42 ± 4.01</td>
<td>0.492</td>
<td>0.007*</td>
</tr>
<tr>
<td>Gender</td>
<td>Male: 12</td>
<td></td>
<td>Male: 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>74.17 ± 9.02</td>
<td>0.991</td>
<td>75.75 ± 11.96</td>
<td>0.980</td>
<td>0.258</td>
</tr>
<tr>
<td>Body height (m)</td>
<td>1.70 ± 0.05</td>
<td>0.486</td>
<td>1.70 ± 0.07</td>
<td>0.977</td>
<td>0.562</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.68 ± 3.78</td>
<td>0.775</td>
<td>26.18 ± 3.42</td>
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<td>0.901</td>
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<tr>
<td>IP AQ-SF</td>
<td>low: 2 moderate: 10</td>
<td></td>
<td>low: 6 moderate: 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant leg</td>
<td>Right: 12</td>
<td></td>
<td>Right: 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCR 60 Dom</td>
<td>0.89 ± 0.33</td>
<td>0.98 ± 0.41</td>
<td>0.002*</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>NonDom</td>
<td>0.95 ± 0.19</td>
<td>0.86 ± 0.31</td>
<td>0.390</td>
<td>0.337</td>
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<tr>
<td>DCR 120 Dom</td>
<td>1.18 ± 0.57</td>
<td>1.24 ± 0.55</td>
<td>0.723</td>
<td>0.847</td>
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<tr>
<td>NonDom</td>
<td>1.40 ± 0.55</td>
<td>1.07 ± 0.33</td>
<td>0.663</td>
<td>0.176</td>
<td></td>
</tr>
</tbody>
</table>

*Significant if p <0.05

Table 2. Knee joint DCR in the treatment group before and after four weeks of intervention

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>p-value</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCR 60 Dom</td>
<td>0.89 ± 0.33</td>
<td>0.85 ± 0.22</td>
<td>0.527</td>
<td>0.189</td>
</tr>
<tr>
<td>NonDom</td>
<td>0.95 ± 0.19</td>
<td>0.98 ± 0.41</td>
<td>0.002*</td>
<td>0.142</td>
</tr>
<tr>
<td>DCR 120 Dom</td>
<td>1.18 ± 0.57</td>
<td>0.98 ± 0.19</td>
<td>0.214</td>
<td>0.381</td>
</tr>
<tr>
<td>NonDom</td>
<td>1.40 ± 0.55</td>
<td>0.94 ± 0.22</td>
<td>0.019*</td>
<td>0.796</td>
</tr>
</tbody>
</table>

*Significant if p <0.05

Table 3. Knee joint DCR in the control group before and after four weeks of intervention

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>p-value</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCR 60 Dom</td>
<td>0.98 ± 0.41</td>
<td>1.00 ± 0.46</td>
<td>0.791</td>
<td>0.078</td>
</tr>
<tr>
<td>NonDom</td>
<td>0.86 ± 0.31</td>
<td>0.78 ± 0.22</td>
<td>0.155</td>
<td>0.441</td>
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<tr>
<td>DCR 120 Dom</td>
<td>1.24 ± 0.55</td>
<td>1.17 ± 0.55</td>
<td>0.405</td>
<td>0.250</td>
</tr>
<tr>
<td>NonDom</td>
<td>1.07 ± 0.33</td>
<td>1.03 ± 0.33</td>
<td>0.422</td>
<td>0.241</td>
</tr>
</tbody>
</table>

Table 4. ΔDCR of the knee joint in treatment and control group

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>Control</th>
<th>p-value</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔDCR 60 Dom</td>
<td>-0.04 ± 0.21</td>
<td>0.02 ± 0.22</td>
<td>0.526</td>
<td>0.263</td>
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<tr>
<td>NonDom</td>
<td>-0.21 ± 0.18</td>
<td>-0.09 ± 0.19</td>
<td>0.129</td>
<td>0.644</td>
</tr>
<tr>
<td>ΔDCR 120 Dom</td>
<td>-0.21 ± 0.54</td>
<td>-0.08 ± 0.30</td>
<td>0.469</td>
<td>0.301</td>
</tr>
<tr>
<td>NonDom</td>
<td>-0.46 ± 0.58</td>
<td>-0.05 ± 0.20</td>
<td>0.036*</td>
<td>0.952</td>
</tr>
</tbody>
</table>

*Significant if p <0.05

Table 2 shows how modified hybrid training affected the treatment group’s knee joint DCR. At knee joint DCR, the paired samples t-test was used because the normality test result with Monte-Carlo indicated that the data were normally distributed. At the conclusion of the study, statistical tests revealed that the treatment group had significantly different values for non-dominant DCR 60°/sec and 120°/sec (p = 0.002 and p = 0.019, respectively). Non-dominant DCR 60°/sec had a large effect size (d > 0.8; d = 1.142). The non-dominant DCR 120°/sec had a moderate effect size (0.5 ≤ d < 0.8) (d = 0.796).

Table 3 compares the knee joint DCR values before and after four weeks of exercise to show how Russian NMES affected the control group’s knee joint DCR. At knee joint DCR, the paired samples t-test was utilized because the normality test result with Monte-Carlo indicated that the data were normally distributed. At the conclusion of the study, statistical tests revealed that there was no significant difference between the treatment group’s dominant and non-dominant DCR values of 60°/sec and 120°/sec.

At the end of the study, the treatment and control groups ΔDCR values for knee joints are compared in Table 4. The independent samples t-test was used because the normality test results with Monte-Carlo indicated that the data were normally distributed. At the conclusion of the study, statistical tests revealed that the control and treatment groups had significantly different values for the ΔDCR 120°/sec on the non-dominant leg (p = 0.036). Non-dominant ΔDCR 120°/sec had a large effect size (d > 0.82) (d = 0.952).
DISCUSSION

In the control group, the average age of the study participants was 32.42 ± 4.01 years, while the average age of the treatment group participants was 30.67 ± 1.88 years. The average age of this study’s participants was older than that of the subjects who participated in the Tourny-Chollet dynamic control ratio on sedentary individuals study in 2002, which had an average age of 22.91 ± 2.06 years.17,18 The study by Sharma in 2022 on the effect of isokinetic strengthening on the dynamic control ratio on healthy men who were between the ages of 18 and 28, with an average age of 24.27 ± 1.48 years in the eccentric group and 24.93 ± 1.16. The average age of this study’s participants was 31.57 ± 3.95 years in the treatment group and 34.71 ± 4.03 years in the control group, which was comparable to the results of the Study by Pringga in 2021 study on leg strengthening in the same population.19

In the treatment group, the average body weight was 74.17 ± 9.02 kg, while in the control group, it was 75.75 ± 11.96 kg. With an average subject weight of 68.23 ± 9.97 kg in the eccentric group and 68.23 ± 9.97 kg in the concentric group, this study subjects weighed more than in Sharma’s 2022 study.18 The study by Pringga in 2021 on leg strengthening in the same population has a lower average body weight compared to this study, in which the treatment group had an average body weight of 62.86 ± 8.98 kg, while the control group had an average body weight of 65 ± 7.68 kg.19 The average body weight of sedentary people in the Tourny-Chollet study was 71.27 kg.17

This study participant’s average height was 1.70 ± 0.05 m in the treatment group and 1.70 ± 0.07 m in the control group. It is comparable to the study by Pringga in which the average height of the study subjects was 1.71 ± 0.06 m and 1.69 ± 0.07 m. The study by Sharma also reported that the subjects’ average heights were nearly identical—172.67 ± 6.05 cm in the eccentric group and 170.27 ± 5.23 cm in the concentric group.18

The average BMI of the treatment group was 25.68 ± 3.78 kg/m², while the control group’s BMI was 26.18 ± 3.42 kg/m², which was categorized as obese grade I according to Asia Pacific Criteria. This study’s subjects’ BMI was higher than that of Pringga’s 2021 study, which has an average BMI of 21.50 ± 2.01 kg/m² and 23.00 ± 2.16 kg/m². The average subject body mass index in Sharma’s 2022 study was also lower, at 22.83 ± 2.70 kg/m² and 22.51 ± 2.03 kg/m².16 Two people (16.7%) in the treatment group had a low IPAQ-SF level, while ten people (83.3%) had a moderate level. Six subjects (50 percent) in the control group had a low IPAQ-SF level, while six subjects had a moderate level. To minimize confounding factors from the subject’s baseline condition prior to undergoing the intervention exercise, researchers used inclusion criteria for low and moderate IPAQ-SF levels. The randomization procedure used to divide subjects into intervention and control groups resulted in an imbalance in the distribution of subjects. Amateur soccer players’ knee joint DCR was lower than that of sedentary subjects at speeds of 60°/sec (0.80 vs. 0.93) and 120°/sec (0.88 vs. 1.03), according to research on sedentary subjects and amateur soccer players. This is due to the fact that amateur soccer players have greater concentric quadriceps strength than sedentary subjects, whereas sedentary subjects and amateur soccer players do not significantly differ in hamstring eccentric strength on dominant and non-dominant limbs.17 Therefore, in order to control confounding factors, further research must include the matching procedure.

On the dominant side, the treatment group had a lower average knee joint DCR (60°/sec: 0.89 ± 0.33, 120°/sec: 1.18 ± 0.57) than the non-dominant side (60°/sec: 0.95 ± 0.19, 120°/sec: 1.40 ± 0.55). On the dominant side, the control group had a higher average knee joint DCR (60°/sec: 0.98 ± 0.41, 120°/sec: 1.24 ± 0.55) than the non-dominant side (60°/sec: 0.86 ± 0.31, 120°/sec: 1.07 ± 0.33). Similar to this study, Tourny’s study on sedentary males found DCR values of 60°/second (0.93) and 120°/second (1.03) in the dominant side have a higher DCR value than the non-dominant side.17 A lower DCR of 60°/sec (0.74 ± 0.09 and 0.76 ± 0.11) compared to this study was found in Sharma’s study of healthy men aged 18 to 28 who regularly participated in 1 to 5 hours of recreational physical activity per week.18 When compared to a speed of 60°/s (0.86 – 0.98), the knee joint’s DCR was higher at 120°/s (1.07 – 1.40). This is consistent with the findings of Tourny’s study, which found that the knee joints of sedentary subjects had a DCR that was 120°/sec (1.03) higher than the speed of 60°/sec (0.93).17

According to the findings of this study, modified hybrid resistance training for four weeks can decrease knee joint DCR value in the treatment group. On the non-dominant side, the knee joint DCR decreased significantly.19-21 The quadriceps femoris’ significant strength increase and the hamstring’s unchanged strength may be the cause of the knee joint’s decreased DCR. Exercises that focus more on the quadriceps muscles than the hamstrings can result in an imbalanced increase in strength. Leg press exercises decreased knee joint DCR at an angular speed of 60°/sec after 8 weeks (-13.6 ± 17.46 %) and 12 weeks (-15.9 ± 14 %) in a study by Da Rosa Orsatto on elderly subject.21 As a result of the leg press exercise’s greater activation of the knee extensor muscles as opposed to the knee flexor muscles, the quadriceps muscles experience the majority of the increased strength.21,22

This study’s quadriceps strength increase is in line with Iwasaki’s study. The study involved healthy, sedentary male participants who participated in hybrid exercise three times per week for six weeks. After three weeks of doing the exercise, the quadriceps’ concentric torque increased by 22% at 30°/sec, 26% at 180°/sec, and the quadriceps’ eccentric torque increased by 12% at 30°/sec, 8% at 180°/sec.21 Better neural adaptation may be the cause of the reduction in knee joint DCR, particularly on the non-dominant leg. Due to less muscle loading, the non-dominant leg motor unit is activated less frequently than the dominant side.21 The non-dominant leg showed greater muscle strength after four weeks of treatment, possibly as a result of neural adaptation in the form of increased motor unit recruitment and firing rate.24 On the dominant side, however, there is not a significant increase in the maximum concentric torque of the quadriceps. Due to the dominance of the limbs in daily activities, this may be due to the motor unit’s already optimal level of activation.
A decrease in the hamstring’s maximum eccentric torque can also contribute to the knee joint DCR reduction, which mostly affects the non-dominant leg. When the hamstring muscles contracted eccentrically under electrical stimulation in a modified hybrid strengthening exercise, the researchers expected the contractions to have a strengthening effect but instead found a decrease in hamstring eccentric torque. This could be the result of reciprocal inhibition, with increased quadriceps muscle activation preventing hamstring muscle activation. Although the majority of neural adaptations cause the agonist muscles to be more active, there is evidence that training may cause the antagonist muscles to be less active. This study did not produce the anticipated effect of increasing maximal eccentric hamstring torsion following the hybrid modification exercise. This could be because the quadriceps muscles were the focus of the modified hybrid exercises in this study. Additionally, this study’s hybrid exercises were modified with conventional stimulation tools to prevent quadriceps hamstring reciprocal strengthening movements. Therefore, in this study, only when stimulated to provide resistance for voluntary quadriceps contractions did the hamstrings experience a strengthening effect from involuntary contractions.

On the non-dominant leg, a critical decrease in DCR was brought about by an expansion in the greatest concentric force of the quadriceps femoris joined by a lessening in the most extreme flighty force of the hamstring. Based on these findings, modified hybrid strengthening exercises may be able to overcome the arthrogenic muscle inhibition in the knee joint that is frequently experienced following ACL reconstruction. The inability to fully activate the quadriceps femoris muscle is a sign of arthrogenic muscle inhibition of the knee joint. The knee flexion reflex pathway, hamstring activation, and quadriceps reciprocal inhibition may be to blame for the decrease in quadriceps activation. It is believed that a pattern of flexor muscle facilitation and extensor muscle inhibition arises from the knee flexion spinal reflex pathway. Poorer knee function is linked to higher hamstring coactivation. In athletes with unilateral ACL reconstruction, it has been demonstrated that reducing hamstring activation after exercises that cause fatigue—hamstring fatigue exercises—significantly increases quadriceps femoris activation. In modified hybrid strengthening exercises, eccentric hamstring contractions caused by electrical stimulation may cause muscle fatigue, which reduces hamstring activation and quadriceps inhibition. Before giving modified hybrid strengthening exercises to patients with arthrogenic muscle inhibition following ACL reconstruction, additional research is required to determine how the exercises affect neuromuscular activation of the quadriceps femoris and hamstring muscles.

The knee joint DCR in the control group of this study after Russian NMES did not differ significantly. This could be because the maximum concentric torque of the quadriceps was higher, but the hamstring’s maximum eccentric torque was higher. The researcher is aware that no studies have examined the impact of Russian protocol NMES stimulation on the knee joint’s dynamic control ratio. According to Park’s study from 2015, resistance exercise and Russian protocol simulation led to a greater increase in quadriceps maximum isometric torque than resistance training alone. In 2020, Akinoglu conducted a second study on ten volleyball athletes using a combination of Russian stimulation and isokinetic training at a 70% maximum tolerated intensity. The findings of Akinoglu’s study indicated a non-significant increase in maximal quadriceps torque and a significant increase in muscle endurance. This could be because the on-off time in this study was shorter—three seconds on (0.5 seconds for the ramp up, two seconds for the hold, and 0.5 seconds for the ramp down) and three seconds off. Park’s research uses 20 seconds off and 5 seconds on. Even though the hamstring was not stimulated, there was a non-significant increase in hamstring torque. This can be influenced by a number of things, including the subject’s familiarity with the eccentric isokinetic test and their physical activity outside of the study.

In this study, the treatment group saw a greater reduction in the non-dominant 120°/sec knee joint DCR than the control group. This could be because the maximum quadriceps and hamstring torques in the two groups change differently. The treatment group showed a greater increase in quadriceps maximum concentric torque (20.17 ± 15.92 FtLbs) than the control group (9.83 ± 11.76 FtLbs). The treatment group saw a decrease in maximum eccentric torsion of the hamstrings of 2.67 ± 21.39 FtLbs, while the control group saw an increase of 8.42 ± 14.66 FtLbs. Variations in the muscle contractions that took place during the intervention could be the cause of the treatment group’s greater quadriceps torsion. The voluntary contraction of the quadriceps is performed against hamstring resistance in a modified hybrid exercise. In the meantime, the control group’s quadriceps contractions were performed voluntarily and without resistance using electrical stimulation. While NMES is more effective at stimulating fast-twitch muscle fibers, voluntary muscle contraction activates both slow-twitch and fast-twitch muscle fibers. The hybrid method is more effective at strengthening than NMES because it employs a more normal pattern of muscle recruitment during voluntary contractions.

In this study, modified hybrid exercise reduced DCR on both sides of the leg at all angular velocities. Non-dominant DCR 120°/sec saw the largest and most significant decrease (32.8%), followed by non-dominant DCR 60°/sec (22.1%), dominant 120°/sec DCR (17.8%), and dominant 60°/sec DCR (4.5%). Leg press exercises decreased knee joint DCR at an angular speed of 60°/sec after 8 weeks (-13.6 ± 17.46 %) and 12 weeks (-15.9 ± 14 %) in an elderly study. The younger age of the subjects in this study may have contributed to the greater DCR change and improved response to resistance training.

Patients with dominant quadriceps weakness or higher hamstring coactivation, such as those with atrophy caused by prolonged immobilization or post-ACL reconstruction patients with arthrogenic muscle inhibition complications, may benefit from hybrid modification exercise as an alternative strengthening exercise or additional therapy. This study also shows that strengthening exercises with the goal
of increasing DCR should not be done with modified hybrid resistance training or the Russian NMES protocol. In order to increase DCR, exercises must include a predominant hamstring contraction, which can’t be done with traditional stimulation tools. The quadriceps and hamstrings will contract more evenly during an unmodified hybrid training exercise. It is possible to conduct additional hybrid training research using a hybrid training system to ascertain how hybrid training affects the dynamic control ratio.

There are limitations to this study. First, this study involved healthy, untrained male subjects and the quadriceps femoris and hamstring muscles; consequently, additional research should be conducted on a different population and with other muscle groups. Second, the hybrid resistance training in this study did not include antagonist-agonist reciprocal contraction because it was done with modifications using conventional stimulation tools. Thirdly, the study did not monitor the subjects’ physical activity outside of the exercise program, which could have affected the results.

CONCLUSION

Modified hybrid resistance training for four weeks provides a reduction in the dynamic control ratio of knee joints. Modified hybrid resistance training for four weeks provides a greater reduction in the dynamic control ratio of the knee joint compared to the Russian protocol neuromuscular electrical stimulation group.

RESEARCH ETHICS

This research has been approved by the Research Ethics Committee, Dr. Soetomo General Hospital, with ethical clearance number 0522/KEPK/XI/2022.

CONFLICT OF INTEREST

There is no conflict of interest in writing this research report.

FUNDING

This research was conducted without grants, sponors, or other sources of funding.

AUTHOR CONTRIBUTION

All authors have made the same contribution in writing the report on the results of this study, from the stage of proposal preparation, data search, and data analysis to the interpretation of research data and presentation of the final report.

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