THE RELATIONSHIP BETWEEN MAXIMAL REPETITION PERFORMANCE AND MUSCLE FIBER TYPE AS ESTIMATED BY NONINVASIVE TECHNIQUE IN THE QUADRICEPS OF UNTRAINED WOMEN

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ABSTRACT. Douris, P.C., B.P. White, R.R. Cullen, W.E. Keltz, J. Meli, D.M. Mondiello, and D. Wenger. The relationship between maximal repetition performance and muscle fiber type as estimated by noninvasive technique in the quadriceps of untrained women. J. Strength Cond. Res. 20(3):699–703. 2006.—The purpose of this investigation was to establish a relationship between the number of repetitions an individual can complete at a predetermined load and their percentage of type II muscle fibers in their quadriceps. Subjects included 22 untrained women between the ages of 18 and 35. Day 1 consisted of noninvasive anthropologic testing, 1 repetition maximum (1RM) testing, and recording repetition performance at 70% 1RM. Day 2 consisted of isokinetic dynamometry to determine muscle fiber composition. Results were obtained and analyzed using the Pearson product correlation coefficient (r). The results demonstrated a fair-to-moderate relationship (Pearson r = −0.48, p = 0.02) that individuals with greater percentages of type II muscle fibers performed fewer repetitions at 70% 1RM. The results of this study demonstrate that muscle fiber type composition is an important variable to consider when designing training or rehabilitation programs.

KEY WORDS. strength, composition, 1RM, variance, noninvasive

INTRODUCTION

Training load and the amount of repetitions performed is the most critical aspect of a resistance-training program (12, 17). Investigators (6, 7) have confirmed repetition variability at varying percentages of an individual’s 1 repetition maximum (1RM) in trained and untrained persons. Muscle fiber type composition has been suggested as the physiological mechanism responsible for this variability (10).

Hoeger et al. (6, 7) set out to determine the exact number of repetitions performed at 40, 60, and 80% of one’s 1RM. Results displayed wide variability amongst several muscle groups tested with the largest standard deviation in the leg press and the smallest in the leg curl. Results ranged from 11 to 20 repetitions for the leg extension at 60% of 1RM completed and at 80% of 1RM scores ranged from 6–13 repetitions. They provided original data on repetition variability at 40, 60, and 80% of 1RM; however, to date there are no documented data of the repetition variability at 70% 1RM. The question raised was whether muscle fiber composition could be the physiological mechanism behind their repetition variability.

Humans have 2 characteristic muscle fiber types that are identified by their contractile properties. Type I, or slow-twitch, fibers are characterized as having slow contraction speed, low power output, high endurance, and a high density of aerobic enzymes. Type II, or fast-twitch, fibers are characterized by fast contraction speeds, high power output, low endurance, and a high density of anaerobic enzymes (1, 10, 23). Several studies have shown that type II muscle fibers are superior in force production but inefficient in the maintenance of force. This makes type II muscle fibers very susceptible to fatigue (3, 8, 20). When examining training variables, aside from mode and intensity of exercise, fiber composition can affect the onset of fatigue (3, 8, 20). Based on this evidence, fiber type variability should affect the number of repetitions performed by an individual, and this variability is not altered by training (5). At a given load with all other parameters under control, those with higher type II composition should show signs of fatigue earlier than those with higher proportional type I composition.

It has been demonstrated that load selection is largely dependent on the specific physiological adaptation an individual seeks. Kraemer and Ratamess (13) have stated that loads above 80% of 1RM are to be used for neural, strength, and hypertrophy adaptations, and this usually corresponds to 6–12 repetitions. At loads less than 60% of 1RM or at 12 or more repetitions, an individual shifts toward experiencing endurance adaptations at the muscular level (17). A minimum of 60% of 1RM must be used if any significant strength gains are to be expected, while 80% of 1RM appears to be the most effective (6).

Karp (10) has speculated on a noninvasive method of determining muscle fiber type that could be used for training utilizing the 1RM principle; however, he states that this method has not been proved scientifically. He proposed that performance of more than 12 repetitions at 80% 1RM signifies the muscle consists of more than 50% type 1 muscle fibers, performance of less than 7 signifies less than 50% type I muscle fibers, and performance between 7 and 12 repetitions signifies an equal proportion of type I and II muscle fibers. He concludes by stating that training within your specific repetition variability according to your genetic predisposition would be more effective. Hickson et al. (5) have shown that repetition variability is not altered following a 16-week resistance-training program. The results of Hickson’s study suggest it may be more beneficial to choose repetitions that correspond to your specific fiber type composition, as suggested by Karp (10), for each muscle group if repetition variability is not altered due to training. This training...
philosophy conflicts with Kramer and Ratamess (13), who do not take into account fiber type composition when determining training loads.

There are various methods used to classify skeletal muscle according to histochemical, morphological, and physiological properties (16). Invasive methods involve histochemically staining for biochemical assay samples obtained from muscle biopsies. The current gold standard is the immunohistochemical method that identifies different forms of the myosin heavy chain molecules (16). Schiaffino et al. (19) discovered this in 1989. The most commonly sampled muscle is the vastus lateralis because of its mixed fiber composition, trainability and accessibility (20). It has been shown that the concentration of type I fibers can range from 96% to as little as 13% in subjects studied (24). It has been shown that women have a greater variability than men in the muscle fiber composition of the vastus lateralis (20). The goal of muscle fiber typing is to make the connection between muscle fiber type and function. Noninvasive techniques attempt to bridge that gap, by utilizing information from all the muscles involved in a given movement (2, 22).

Thorstensson and Karlsson (23) in 1976 demonstrated a strong relationship between Isokinetic dynamometry at 180° s⁻¹ and muscle fiber composition that allowed for the development of a regression equation. Their regression equation has been utilized countless times in the literature as a valid noninvasive technique of fiber typing. However, they utilized a small athletic sample of ten males and did not take into account anthropological measurements when creating their regression equation. In 1979, Campbell et al. (2) questioned Thorstensson’s findings and indicated that muscle fiber composition is usually not correlated with objectives measures of performance. Although they stated that it was possible to predict muscle fiber composition from selected laboratory tests when using a multiple regression approach. Lexell and investigators (14, 15) have shown that single biopsies are poor estimators of muscle fiber types for the whole muscle. They determined that at least 3 samples from different depths are recommended to improve the precision of the estimate. In response that muscle biopsy methods are not without problems, Suter et al. (22) developed a noninvasive method that produced a multiple regression equation to predict the proportion of type II muscle fibers of the quadriceps muscle of men and women utilizing Isokinetic dynamometry and fat-free mass (FFM). The final model revealed a correlation coefficient of $r = 0.72$ that was used in creating their regression equation.

The purpose of this investigation was to establish a relationship between the number of repetitions an individual can complete at a predetermined load and their composition of type II muscle fibers. Based on our review of current literature, muscle fiber physiology suggests that repetition variability during isometric exercise will exist in correlation to fiber composition. However, to the authors’ knowledge, there are no studies to support this hypothesis. Individuals with higher percentages of type II muscle fibers will perform fewer repetitions than those with lower percentages of type II muscle fibers. The results of this study may assist in validating an easy and inexpensive field test that can be used for predicting muscle fiber composition, elucidate the physiological mechanism behind repetition variability, and document original data on the number of repetitions performed at 70% 1RM.

Subjects
Twenty-two untrained women between the ages of 18 and 35 years (mean $= 24.4$, $SD = 3.5$) were recruited from a group of women who met our inclusion and exclusion criteria. This sample of convenience consisted of volunteers from the New York Institute of Technology community. The Institutional Review Board at New York Institute of Technology approved this study, and all subjects read and signed an informed consent form prior to participating in the study. Subjects were screened for any neuromuscular or orthopedic disorders that might influence their ability to take part in the study.

Procedures
Data collection occurred on 2 days. A maximum 1-week rest interval was established between day 1 and day 2 of the study, with indications to start day 2 as soon as any signs of delayed-onset muscle soreness have subsided. Day 1 involved collecting the anthropological data required for the regression equation, the 1RM test, and the measuring of the repetitions performed at 70% of the 1RM. Day 2 consisted of the isokinetic testing required in order to complete the regression equation as per Suter’s protocol (22).

Day 1
Body fat. A Lange skinfold caliper (Beta Technology, Cambridge, MD) was used to measure subcutaneous fat to determine body fat. All measurements were taken of the right side of the body. Sites measured included triceps, suprailliac region, abdomen, and thigh (9). Guidelines that were used to obtain the measurements were as follows: The skinfold was grasped firmly by the thumb and forefinger at the sites listed above. The caliper was applied to the skinfold, and after 2 seconds, the caliper...
dial was read. The reading was recorded in millimeters. This procedure was repeated 3 times at all sites. After all measurements were collected and summarized, body fat percentages were calculated using equations given by Jackson and Pollock (9). Height and weight of each subject were also measured using a standard scale.

**Fat free mass of the thigh.** Procedures were followed as described by Suter (22). Body fat calipers were used to determine thigh density, and circumferential measurements were used to determine thigh volume. These measurements were taken of the dominant limb at 3 sites: subtrochanteric, mid-thigh, and supra patellar. Density and volume of the thigh were used to determine mass (mass = density/volume). The variables were determined by (a) density = 4.201/(percent fat/100 + 3.813), (b) thigh dimensions are similar to a truncated cone, from which volume was derived; this is a multiple of the girth measurement at each site and the length between these sites, and (c) mass = density/volume.

**Dominant leg determination, 1RM determination, and repetition performance.** Prior to testing, each subject was asked to casually step on onto an 18-inch platform 5 times to determine leg dominance. The dominant limb was the leg the subjects used the majority of the time. The 1RM was determined through a trial-and-error method. Due to the nature of the trial-and-error method a warm up was built into the test. Prior to testing, each subject was instructed to cycle on the ergometer for 3 minutes at an intensity of 1–2 on the rate of perceived exertion scale, followed by performing 1 set of quadriceps and hamstring stretches for 30 seconds. The 1RM testing for the dominant quadriceps has been previously described in the literature by Gulick et al. (4). All lifts were performed using the leg extension machine (Body Masters, Westchester, NY). Following a 15-minute rest period, the subjects performed as many repetitions of knee extension until volitional fatigue at a weight of 70% of their 1RM. The participant’s trial was over once full extension was no longer achieved. The repetition for each lift was done in a continuous cadence using a metronome and verbal cues until a maximal number of repetitions were accomplished. The number of repetitions was used for subsequent data analysis.

**Day 2**

**Isokinetic testing.** Isokinetic testing was measured using a Cybex Norm II Isokinetic machine (Lumex Co., Ronkonkoma, NY), calibrated according to manufacturing standards prior to each day of testing. Each subject performed a similar warm up as outlined in day 1, consisting of 3 minutes of cycling and stretching. Functional testing for the regression analysis was done in 1 session with power testing performed before the fatigue test. The subjects were secured in position after adjustment of the height of the dynamometer and the length of the support lever, allowing the axis of rotation of the dynamometer to be aligned with the subject’s knee joint. Each subject was stabilized at the chest, waist, and thigh with a strap. A shin strap was secured to the lower leg proximal to the malleoli; the test was performed on the dominant limb. Protocols of the functional testing suggested by Suter (22) were used. To determine power, participants performed 1 maximal effort knee extensor contraction at an angular velocity of 280°·s⁻¹. This was repeated 3 times with 2-minute intervals between each attempt. The best effort was recorded for statistical analysis. Power is calculated as the product of peak torque of the set and its corresponding angular velocity (W·kg⁻¹). Dividing by the fat-free mass of the thigh (FFMT) normalizes all power values. During the fatigue test, participants performed 55 knee extensor contractions at an angular velocity of 90°·s⁻¹. The peak torque achieved at the 55th repetition was the recorded value. This test was only performed once due to the extended time frame required to recover from fatigue testing. Participants were able to view their real-time performance on the Cybex monitor while being given verbal encouragement to perform maximal effort for each contraction. Results from both tests were used for the regression equation developed by Suter (22).

The relationship between maximal repetition performance and muscle fiber type was analyzed utilizing the Pearson product correlation coefficient (r). The relationships between 1RM, body weight, FFM, and percentage of type II muscle fibers were also analyzed utilizing the Pearson product correlation coefficient (r). Central tendencies reported included mean, standard deviation, and range values of the variables. Statistical significance was accepted at p ≤ 0.05. All statistical analyses were performed with SPSS, version 11.5 (SPSS, Inc., Chicago, IL).

**RESULTS**

Table 1 summarizes the physiological characteristics of the subjects. The results of the Pearson product correlation coefficient (r) between the percentage of type II muscle fibers and the number of repetitions performed was −0.48 (p = 0.02). Table 2 presents the results of Pearson product correlations between the percentage of type II muscle fibers and the 1RM, body weight, and FFM. The

**Table 1. Physiological characteristics of the subjects.***

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>161.23</td>
<td>±6.22</td>
<td>151–172</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.10</td>
<td>±10.10</td>
<td>48.18–84.09</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>94.38</td>
<td>±14.63</td>
<td>74.10–132.70</td>
</tr>
<tr>
<td>% Body fat</td>
<td>27.21</td>
<td>±3.68</td>
<td>19.70–33.90</td>
</tr>
<tr>
<td>1RM</td>
<td>66.65</td>
<td>±14.60</td>
<td>45–100</td>
</tr>
<tr>
<td>% Type II</td>
<td>62.20</td>
<td>±7.40</td>
<td>48.05–76.60</td>
</tr>
<tr>
<td>% Type II and FFM</td>
<td>0.12</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>% Type II and Weight</td>
<td>0.13</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>% Type II and FFM</td>
<td>0.03</td>
<td>0.88</td>
<td></td>
</tr>
</tbody>
</table>

* FFM = fat-free mass; 1RM = 1 repetition maximum.

**Table 2. Pearson product coefficient correlations (r).***

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Type II and repetition performed</td>
<td>−0.48</td>
<td>0.02</td>
</tr>
<tr>
<td>% Type II and 1RM</td>
<td>0.13</td>
<td>0.57</td>
</tr>
<tr>
<td>% Type II and Weight</td>
<td>0.12</td>
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<td>−0.03</td>
<td>0.88</td>
</tr>
</tbody>
</table>

* 1RM = 1 repetition maximum; FFM = fat-free mass.
The correlation coefficient of $r$ between muscle fiber type composition and repetition variability was determined (10–12). Although muscle fiber transformations have been established between types IIa and IIb with specific strengthening protocols, such transformation has not been noted between types II and I muscle fibers (1, 21).

Since muscle fiber transformation does not occur, specific training regimens can be used to target specific muscle fiber compositions.

The question remains as to whether one should train according to their muscle fiber composition. Hickson et al. (5) have shown that repetition variability was neither compromised nor enhanced following a 16-week training program. Repetition performance at the same relative work rates (80, 60, and 40%) remained unchanged. Fiber type composition appears to be responsible for repetition variability that did not alter with training.

What is the optimal number of repetitions to be used for exercise? Because the results of this study have determined a relationship between the number of repetitions and muscle fiber composition, a more practical method to determine the number of repetitions that can be used for any given percentage of the 1RM and any muscle group is to use the number of repetitions performed to muscular failure as the training range. Why train a muscle group with high number of repetitions if it contains a high percentage of type II muscle fibers? Different muscle groups and loads will present with repetition variability due to its specific muscle fiber composition. Training studies that will compare standard repetition protocols versus repetitions based on muscle fiber type composition will assist in answering this question.

The limitation to this study was not performing muscle biopsies to accurately measure muscle fiber type composition. However, at least 3 or more biopsies from different depths of the muscle are required to estimate muscle fiber composition (14). The quadriceps are composed of 4 different muscles that are involved with producing knee extension. That would have necessitated 12 separate biopsies. Noninvasive testing may provide the superior connection between muscle fiber types and function because it takes into account data from the entire muscle. Another limitation was the inability of the regression equation to differentiate between the subset of the type II fibers, the type IIa and the type IIb.

This study was performed on the quadriceps of untrained women between the ages of 18 and 35. This study should be replicated using other populations such as trained women and men, untrained men, different age groups, and other muscle groups. It should also be repeated using muscle biopsies or other valid invasive or noninvasive procedures to determine muscle fiber composition.

These findings suggest there is a relationship between muscle fiber composition and repetition variability. This relationship can be utilized to establish field tests to determine fiber type. The optimal number of repetitions one should use for training and rehabilitation should focus on muscle fiber composition of the specific muscle or muscle groups.

**PRACTICAL APPLICATIONS**

Because a fair-to-moderate degree of correlation was established, it is possible to accept our hypothesis that individuals with higher percentages of type II muscle fibers will perform fewer repetitions than those with lower per-

![Figure 1](image-url)
centages of type II muscle fibers. The results of this study demonstrate that muscle fiber type composition is an important variable to consider when designing training or rehabilitation programs. Instead of assigning an arbitrary number of repetitions and sets to every single trainee or patient, the individual’s muscle fiber type should be taken into account when designing programs. By considering this variability, training and rehabilitation programs will be safer, more efficient, and more appropriate for the individual.

References


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