Peak Torque, Average Power, and Hamstrings/Quadriceps Ratios in Nondisabled Adults and Adults With Mental Retardation

Ronald V. Croce, PhD, Kenneth H. Pitetti, PhD, Michael Horvat, EdD, John Miller, PhD

ABSTRACT. Croce RV, Pitetti KH, Horvat M, Miller J. Peak torque, average power, and hamstrings/quadriceps ratios in nondisabled adults and adults with mental retardation. Arch Phys Med Rehabil 1996;77:369-72.

Objective: To compare isokinetic hamstring and quadriceps peak torque (Nm), average power (watts), and corresponding hamstring/quadriceps (HQ) ratios (as percentages) of adult men with Down syndrome (DS), with mental retardation without Down syndrome (NDS), and nondisabled sedentary controls (SC).

Design: Repeated measures analysis of variance.

Setting: Subjects were tested at a university exercise science laboratory.

Subjects: Volunteer sample of 35 subjects: SC ($n = 13$), DS ($n = 9$), and NDS ($n = 13$).

Intervention: Subjects performed isokinetic strength tests at 60°/sec and 90°/sec using gravity effected torque procedures. Subjects with DS and NDS performed the test on two separate days with best results selected for statistical comparisons. Sedentary controls performed the test once.

Main Outcome Measures: Isokinetic hamstring and quadriceps peak torque and average power, and corresponding HQ ratios on a Cybex 340 isokinetic dynamometer.

Results: In all isokinetic parameters measured, sedentary controls demonstrated significantly higher scores than subjects with DS and NDS. There was no significant difference between subjects with DS and NDS, although mean peak torque and average power scores were greater in subjects with NDS. Finally, there were no significant differences in peak torque and average power HQ ratios across groups ($p > .01$), although group mean peak torque HQ ratios were greatest for sedentary controls (range = 61% to 63%) and approximated accepted HQ ratio norms, and lowest for subjects with DS (range = 40% to 46%).

Conclusions: Individuals with mental retardation are in need of progressive resistance exercise programs to improve hamstring and quadriceps strength and normalize HQ strength and power ratios.

STRENGTH has been described as the "force or tension a muscle can exert against a resistance in one maximal effort,"[1] and has been considered fundamental to an individual's ability to perform efficient, coordinated movements.[2] In individuals with mental retardation, strength has been found to be an integral component of physical fitness, essential for effective performance in vocational, leisure, and sport-related activities.[3,4]

One of the most reliable means of measuring strength has been isokinetic dynamometry.[5] Isokinetic exercise is defined as a dynamic movement involving contractions at a preselected constant angular velocity whereby the resistance encountered is relative to the force produced by the individual.[6] Since the measured output of isokinetic testing (torque) is the rotational force about a joint, direct comparisons can be made between movement velocities and between individuals.[7]

Isokinetic scores have commonly been reported in absolute units such as Newton meters (Nm) of torque and joules (J) of work accomplished, but data have also been reported as ratios in relation to body weight or joint movements. One of the major advantages of ratio data is that comparisons are normalized, typically with subjects acting as their own standard. As such, ratios provide an estimate of relative capability or balance of the muscle groups in question.[8,9] Several investigators have suggested that an imbalance of the ratio of the hamstring and quadriceps muscle groups (HQ ratio) may be a deciding factor in knee joint stability and knee joint muscular injuries.[10]

In a previous study by Pitetti and colleagues,[11] it was reported that adults with mental retardation demonstrated lower isokinetic leg strength than nondisabled sedentary adults. In this study, leg strength was reported in terms of knee extension and flexion. Parameters measured were peak torque, peak torque percentage body weight, average power, and average power percentage body weight at a speed of 60°/sec. However, it has not been determined if these strength parameters differ appreciably at speeds of 90°/sec. Furthermore, although peak torque HQ ratios tend to be between 50%[12,13] and 60%[14] in nondisabled adults, there is a paucity of data concerning peak torque HQ ratios of adults with mental retardation. Because of the importance of obtaining normative data on individuals with mental retardation, especially data relating to peak torque and average power HQ ratios, and the dearth of research on the isokinetic characteristics of this population, this study was undertaken.

It was the purpose of this study, therefore, to: (1) determine the effect of different angular velocities (ie, 60°/sec and 90°/sec) on hamstring and quadriceps peak torque and average power of adults with mental retardation with Down syndrome and without Down syndrome; (2) determine if results seen with these subjects differed from nondisabled sedentary controls; and (3) document peak torque and average power HQ ratios for the three groups of subjects and determine if differences existed between groups.

METHODS

Subjects

Men with Down syndrome (DS; $n = 9$), with mental retardation but without DS (NDS; $n = 13$), and nondisabled sedentary controls (SC; $n = 13$) participated in the study. Down syndrome

From the Department of Kinesiology, University of New Hampshire (Drs. Croce and Miller), Durham, NH; Wichita State University (Dr. Pitetti), Wichita, KS; and University of Georgia (Dr. Horvat), Athens, GA.

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Reprint requests to Ron Croce, PhD, Department of Physical Education, New Hampshire Hall, 124 Main Street, Durham, NH 03824-3559.

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Table 1: Descriptive Characteristics of Subjects

Characteristic	DS (n = 9)	NDS (n = 13)	SC (n = 13)
Age (yr)	25.9 ± 4.3	24.1 ± 3.6	24.2 ± 3.4
Height (cm)*	153.8 ± 13.8	170.8 ± 10.7	171.3 ± 11.8
Weight (kg)	79.0 ± 16.8	78.1 ± 23.0	74.0 ± 8.5
Intelligence Quotient (IQ)	56.4 ± 3.6	59.8 ± 4.4	

* NDS and SC subjects were significantly taller ($p < .01$) than DS subjects.

and NDS subjects had similar intelligence quotients (IQs) as previously determined on either a Wechsler Adult Intelligence Scale or the Stanford Binet Scale. The mean IQs of the DS and NDS subjects were within a range considered to represent individuals with mild to moderate mental retardation (MR). Medical records were used to ascertain whether subjects were diagnosed with DS.

Subjects with MR were recruited from two sheltered workshops or vocational training centers for the handicapped. Jobs at these sites involved light physical activity for an average of 5.5 hours, 5 days per week. Sedentary controls were university students (see table 1 for descriptive statistics). Height and weight for all subjects were measured on a standard physician's scale (Detecto[a]) and converted to the metric system. Informed consent was obtained from the subjects or their legal guardians. This study was in accordance with university guidelines for research involving human subjects.

Protocol

Hamstring and quadriceps strength were measured from the dominant side. The dominant leg was defined as the leg the subject used or would use to kick a ball.[15] Subjects were tested for hamstring and quadriceps peak torque (Nm) and average power (watts) at velocities of 60°/sec and 90°/sec on a Cybex 340 isokinetic dynamometer.[b] Average power is an expression of work per unit of time and was used as an indicator of subjects' work rates.

The choice of 60°/sec and 90°/sec was based on the previous work of Pitetti and colleagues[11,16] and Heitman and Kovaleski,[17] who documented high reliability of isokinetic strength measurements at these angular velocities. For subjects with MR, testing was performed on two different days, with 48 to 96 hours between test days. Best test results were used for statistical comparison. This protocol has been demonstrated to be reliable when measuring isokinetic strength of adults with MR.[16] Sedentary controls were tested once.[11]

Subjects initially performed warm-up, submaximal exercise for 6 to 10 minutes on either a Schwinn Air-Dyne ergometer[c] or a treadmill. After the warm-up period, subjects performed ten practice repetitions, beginning at a low effort and gradually increasing to efforts of high intensity, for leg extension and flexion at a speed of 60°/sec. Subjects then performed two sets of three maximal efforts at 60°/sec. Following a 1-minute rest, subjects performed two sets of three maximal efforts at 90°/sec. Testing protocol, gravity effected torque (GET) procedures, testing positions, and joint stabilization conformed to guidelines outlined in the Cybex testing manual.[18] On the Cybex, GET is the torque resulting from the effect of gravity on the combined weight of leg and dynamometer arm at the midpoint of extension and flexion movement. Failure to consider GET can greatly underestimate quadriceps peak torque and average power and overestimate hamstring peak torque and average power.[19] Subjects were verbally exhorted to perform as forcefully as possible.

Statistical Analysis

Means ($\bar{x}$) and standard deviations (SD) were calculated for subjects' descriptive statistics and for the following strength parameters: hamstring peak torque (Nm) and average power (watts), quadriceps peak torque and average power, and peak torque and average power HQ ratios. Peak torque and average power were analyzed in separate 3 (group) × 2 (muscle group) × 2 (velocity) repeated measures analysis of variance (ANOVA); HQ ratios were analyzed using a 3 (group) × 2 (velocity) ANOVA. The conservative Greenhouse-Geisser correction factor was used to evaluate observed within-group F ratios. Between-group post hoc comparisons consisted of a Tukey test; within-group post hoc comparisons were planned orthogonal contrasts using means and regression coefficients. Because of the large number of statistical comparisons, an alpha level of .01 was used to protect against type I error. Intelligence quotients of DS and NDS groups were compared with a student t test, using an alpha level of .05.

RESULTS

Peak Torque. Means and standard deviations for hamstring and quadriceps peak torque are listed in table 2. Data analysis indicated significant group ($F_{2,32} = 31.16$, $p < .0001$), muscle group ($F_{1,32} = 219.0$, $p < .0001$), and velocity ($F_{1,32} = 37.28$, $p < .0001$) main effects and a muscle group × velocity ($F_{1,32} = 16.64$, $p < .001$) interaction effect. Post hoc analysis indicated that: (1) sedentary controls displayed significantly greater hamstring and quadriceps peak torque than subjects in DS and NDS groups, with no significant difference between subjects in DS and NDS groups; (2) subjects in all groups displayed greater hamstring and quadriceps peak torque values at an angular velocity of 60°/sec than at 90°/sec; and (3) quadriceps peak torque was greater than hamstring peak torque.

Average Power. Means and standard deviations for hamstring and quadriceps average power are found in table 2. Data analysis indicated significant group ($F_{2,32} = 26.73$, $p < .0001$), muscle group ($F_{1,32} = 226.0$, $p < .0001$), and velocity ($F_{1,32} = 62.66$, $p < .0001$) main effects, and group × velocity ($F_{2,32} = 8.63$, $p < .001$) and muscle group × velocity ($F_{1,32} = 34.50$, $p < .0001$) interaction effects. Post hoc analysis indicated that: (1) sedentary controls had significantly higher hamstring and quadriceps average power values than subjects in DS and NDS groups, with no significant difference between subjects in DS and NDS groups; and (2) subjects in NDS and SC groups displayed significantly greater hamstrings and quadriceps average power values at an angular velocity of 90°/sec than at 60°/sec, with no significant difference found between the two velocities with subjects in the DS group ($p > .01$).

HQ Ratios. Means and standard deviations for peak torque and average power HQ ratios are found in table 2. Data analysis indicated no significant differences in group peak torque and average power HQ ratios ($p > .01$), although mean peak torque HQ ratios were greatest in the SC group (range = 61% to 63%) and lowest in the DS group (range = 40% to 46%). Peak torque ratios for sedentary controls approximated accepted HQ ratio norms.[14]

DISCUSSION

Significant group differences were found in peak torque and average power for the muscle groups tested. Sedentary controls were shown to produce significantly greater peak torque and average power than subjects with DS and NDS. These data are congruent with the findings of Pitetti and colleagues,[11] which indicated that individuals with DS and NDS exhibited inferior leg strength and average power than SC individuals. Unlike those results, however, our data indicated no significant difference between DS and NDS groups, although mean peak torque and average power scores were greater in subjects with NDS.

Table 2: Peak Torque, Average Power, and Hamstring/Quadriceps (HQ) Ratios by Group and Angular Velocity

	DS		NDS		SC	
	60°/sec	90°/sec	60°/sec	90°/sec	60°/sec	90°/sec
Peak Torque (Nm)						
Hamstrings	45.5 ± 22.6	38.0 ± 23.1	71.3 ± 37.1	50.3 ± 23.9	146.4 ± 48.6	132.9 ± 40.0
Quadriceps	111.5 ± 36.9	82.4 ± 33.0	141.2 ± 50.3	104.9 ± 48.2	238.8 ± 48.6	213.2 ± 42.3
HQ Ratio	40.0 ± 12.0	46.0 ± 20.7	50.0 ± 16.3	48.0 ± 16.4	61.0 ± 14.3	62.0 ± 14.7
Average Power (watts)						
Hamstrings	30.3 ± 16.8	35.5 ± 24.2	44.6 ± 20.3	62.7 ± 28.9	104.7 ± 41.2	136.2 ± 58.3
Quadriceps	74.6 ± 28.0	86.33 ± 33.8	86.8 ± 29.6	122.5 ± 36.7	164.1 ± 38.1	218.5 ± 55.7
HQ Ratio	40.0 ± 14.6	41.0 ± 18.3	51.0 ± 15.6	51.0 ± 20.2	63.0 ± 14.3	62.0 ± 16.0

Scores represent means ± SD (see text for statistical significance).

The nonsignificance was probably caused, in part, by large standard deviations found in the data and the use of a .01 alpha level rather than the traditional .05 level of significance.

We also found that peak torque decreased as velocity increased. This finding is well documented in the literature with both nondisabled individuals[7,8,13] and individuals with MR.[11,17] Conversely, we found average power increased as velocity increased. This, too, is well documented in the nondisabled literature.[20,21] No data on average power are available, however, for individuals with MR.

When examining peak torque and average power HQ ratios across groups, no significant differences were found at any of the test velocities. In addition, there were no significant differences between velocities within each group. Although no statistical differences were found, sedentary controls had greater peak torque and average power HQ ratios than subjects with DS and NDS (table 2). Once again, it must be noted that an alpha level of .01 was used in our investigation, compared to the usual .05 level used by most researchers.

Although there are large discrepancies in the literature regarding optimal peak torque HQ ratios, clinicians agree that this ratio is essential when evaluating knee joint integrity.[22] The peak torque HQ ratio for the sedentary controls in our study was lower than those reported by Wyatt and Edwards (72%),[13] higher than those reported by Moffroid and coworkers (50%),[22] and similar to those reported by Coplin,[23] Holm and associates,[20] Nosse,[14] and Scudder,[24] all of whom found about a 60% ratio. Based on these data, peak torque HQ ratios of our subjects with MR appear to be too low, especially those for subjects with DS.

Although a trend was found for hamstring and quadriceps peak torque to decrease with increasing velocity, and vice versa for average power, these trends had little impact on peak torque and average power HQ ratios. In our study, HQ ratios were shown to remain relatively constant, irrespective of test velocity. This finding was both substantiated by previous research[7,24] and in conflict with other research.[13,25,26] It must be noted, however, that differences in velocity tested in our study were quite small and at the low end of the velocity curve (60°/sec and 90°/sec), compared to data of Wyatt and Edwards[13] and Klopfer and Greij,[25] and may account for the consistent HQ ratios we observed, despite changing torque values with changing velocities.

In terms of utility, HQ ratios based on total work parameters, which are represented by the total area under the torque curve, give more information about muscular performance than does a single point on the curve. Hence, the average power HQ ratio (work/sec) may be a parameter of considerable importance in isokinetic testing because it reflects muscular efficiency (work rate intensity). In our study, peak torque and average power ratios were consonant in each group (table 2). Unfortunately, data on average power HQ ratios are only parsimonious in the literature for nondisabled individuals,[20] and nonexistent in the MR literature, making comparisons limited. At 60°/sec, average power HQ ratios of our sedentary controls tended to be slightly lower (63.0 watts) than those found by Holm and associates (71.3 watts).[20]

CONCLUSIONS

There are serious implications for individuals with MR if results of this study and that of Pitetti[11] are representative of this population in general. It has been clearly demonstrated that body strength (1) is valuable for recreation, sport, and activities of daily living,[27] (2) is a prerequisite for many vocational skills,[28] and (3) is imperative for work productivity[4,29] in this population. Therefore, it is essential that professionals working with individuals with MR provide them with ample opportunity for exercise programs that improve muscular strength and efficiency.

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Suppliers

a. Detecto Scales, Inc., 103-00 Foster Avenue, Brooklyn, NY 11236.
b. Cybex: A division of Lumex Inc., 2100 Smithtown Avenue, Ronkonkoma, NY 11779.
c. Excelsior Fitness Equipment Co., 615 Landwehr Road, Northbrook, IL 60062.