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Relationships between isoinertial lumbar dynamometry parameters and demographic parameters in chronic low back pain patients

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Abstract The purpose of this study was to investigate which demographic parameters are most important in relation to lumbar dynamometry performance in patients with chronic low back pain (LBP). Forty-five chronic LBP patients participated in this study. Gender, age, weight and height were determined and a lumbar dynamometry measurement was carried out, using the Isostation B200. Student's *t*-test, ANOVA techniques and correlation coefficients were used to investigate the relationships between each demographic parameter and lumbar dynamometry performance. Stepwise multiple linear regression analyses were performed afterwards to determine which demographic parameters are most important in relation to lumbar dynamometry performance. Results indicate significant relationships (1) between gender, height, weight and all lumbar dynamometry parameters and (2) between age and three of the six isometric torque parameters. No significant relationship

was found between age and maximum velocity parameters. Results of the stepwise multiple linear regression analyses show that the demographic parameters explain 27–47% of the variance in maximum isometric strength parameters and 19–25% of the variance in maximum velocity parameters. Gender is the most important demographic parameter, being related to nearly all maximum isometric torque parameters (percentage explained variance 6–37%) and height is the only important demographic parameter related to the velocity parameters (percentage explained variance 19–25%). Weight and age account for only a small amount of variance in lumbar dynamometry parameters (percentage explained variance 5–7%), meaning that these parameters are non-relevant predictors.

Key words Isostation B200 · Low back pain · Gender · Age · Weight · Height

Introduction

Interest in developing isoinertial measurement techniques to evaluate the low back muscle function in patients with chronic low back pain has increased during the last few years. Patient performance is compared with standards estimated for healthy persons in order to gain insight into the low back muscle function. A problem inherent in mus-

cle performance testing, however, is the large degree of intersubject variability. The absolute magnitude of force or velocity produced by individuals will vary according to different populations, depending on various factors, e.g. gender, age, weight and height. For example, the force exerted by a 60-year-old woman will be different from that expected for a 20-year-old man. The problem facing the clinician is interpretation of the obtained muscle performance. One way to handle this large intersubject variability

ity, thus making the assessment of low back muscle function more accurate, is to adjust the values obtained on the basis of clinical data (e.g. gender, age, weight and height).

For this reason, a considerable amount of research has been conducted into relationships between lumbar dynamometry performance and demographic parameters in both low back pain patients and healthy subjects [e.g. 9–11, 13, 14, 16, 17, 22]. There is consistent evidence from all these reports that men show higher performance levels than women. However, the results of measurements showing the relationship of trunk isomeasures to body weight are equivocal. Some studies showed significant positive relationships [1, 9], other studies found only weak correlations between body weight and torque [10, 16] or concluded that the relationship with body weight was due to a two-way interaction with gender [5].

Results of the relationship of trunk isomeasures to age are also equivocal. Some studies found no significant relationship to age [14, 18], whereas others found a fall in performance when age increases [5, 11, 22]. There is no consensus about the age at which any fall in performance begins.

The relationship between height and trunk isomeasures has been investigated less often. Some studies showed no relationship between height and force parameters [14, 17], others found that age, height and weight are major factors in determining true isokinetic torque [9], again others found that of the parameters age, gender, body weight and height, only height showed positive and significant relationships with isokinetic torque parameters [3].

In most of the above-mentioned studies the relationships were investigated for each demographic parameter separately, or only one other demographic parameter was taken into account. Only Jerome et al. [9] and Estlander et al. [3] investigated the relationship between lumbar dynamometry parameters and multiple demographic parameters using stepwise multiple linear regression analysis. In both studies an isokinetic device was used. No scientific papers were found concerning the relationship between demographic parameters and *isoinertial* lumbar dynamometry performances in a group of low back pain patients taking multiple demographic parameters into account. *Isoinertial* lumbar dynamometry devices measure different variables to those obtained by isokinetic devices; velocity is the most sensitive, and therefore the most important, parameter in *isoinertial* lumbar dynamometry, whereas isokinetic devices can only measure torque and torque-derived parameters. In addition, the differences in mechanical principles between isokinetic and *isoinertial* devices may be reflected in a different influence of demographic parameters.

Therefore, it was the purpose of this study to investigate relationships between demographic parameters and lumbar dynamometry performances in low back pain patients, using an *isoinertial* device. Special attention was paid to establishing which demographic parameters are most important in these relationships.

Relationships were investigated in low back pain patients. The main reason is that lumbar dynamometry measurements are most often used in low back pain patients, and when controlling for demographic parameters is considered, it should be based on data from the same group.

Material and methods

Subjects

Forty-five chronic low back pain patients (31 men and 14 women) being on a waiting list for treatment at the rehabilitation centre participated in this study. Mean age was 40 (SD 9) years, mean weight was 81.4 (SD = 13.9) kg and mean height was 177 (SD 9) cm.

Exclusion criteria for this study were respiratory and cardiovascular disorders, pregnancy, diseases of the eyes and eye surgery in the past 6 months, claustrophobia, back surgery in the previous 6 months and deformity of the spine (e.g. scoliosis).

All subjects signed a written informed consent prior to participation.

Procedure

Lumbar dynamometry measurements were carried out and gender, age, weight and height were determined. Data were collected in a single session which lasted for about 1 h.

The Isostation B200 (Isotechnologies, Hillsborough, N.C.) was used for data collection. The B200 is a triaxial dynamometer that measures angular position, angular velocity and torque about the three primary movement axes of the low back (sagittal, coronal and transverse). The machine is interfaced to a personal computer via an analogue-to-digital convertor board that samples nine channels of signals from the B200 at a rate of 50 Hz per channel. The computer is also used to control the resistance that is provided independently about each axis. Electronically regulated hydraulic pumps associated with each axis provide this resistance. The B200 has a self-calibration sequence built into its software, and this procedure was carried out at the beginning of each testing day. The reliability of the B200 performance measurements has been previously reported by several investigators [6, 15, 19].

Before each lumbar dynamometry measurement a warming-up was carried out by the patient on a bicycle for 5 min.

The subject was positioned in the standing posture in the B200, with the lumbosacral junction aligned with the flexion/extension axis of the machine. The subject was firmly restrained using the straps and pads provided, according to the instructions provided by the manufacturer [7]. Next, the subject was allowed to practise to get a feel for the movements carried out during the measurements.

The lumbar dynamometry measurements were carried out according to a standard protocol consisting of the following consecutive measurements Occupational Orthopaedic Center (OOC) protocol [2]:

1. Measurements of unresisted range of motion in each of the six movement directions (flexion, extension, left and right lateral flexion, left and right rotation). Subjects were instructed to move in a slow controlled manner to reach their maximum range of motion.
2. Maximum isometric torque measurements in each of the six movement directions.
3. Dynamic measurements. Each subject was asked to move as fast as possible five times in each plane (sagittal, coronal and transverse) against a resistance set at 25% then 50% of the maximum isometric torque generated during the respective isometric tests.

Data analysis

The data obtained were converted to an ASCII format and analysed using SPSS for windows. The selected parameters in each of the six movement directions used for data analysis were:

1. Maximum isometric torque (MVC)
2. Maximum velocity measured during dynamic tests against a resistance of 25% MVC (MXV25)
3. Maximum velocity measured during dynamic tests against a resistance of 50% MVC (MXV50)

Range of motion parameters were excluded from analysis as, in a previous study, it was shown that these parameters are not very reliable [6]. Dynamic torque parameters were not taken into account as these parameters are related to the set resistances and are thus related to the maximum isometric torque.

The relationships between maximum isometric torque, maximum velocity parameters and each demographic parameter were investigated separately first.

Relationships between lumbar dynamometry parameters and gender were investigated using *t*-tests. Relationships between weight, height and lumbar dynamometry parameters were investigated using correlation coefficients. Because the effects of age cannot be assumed to be linear, age groups were used for analysis. Subjects were divided into four groups: less than 30 years, 30–39 years, 40–49 years and older than 50 years at the time of testing. ANOVA techniques were used to investigate the relationships between lumbar dynamometry parameters and age.

ANOVA compares the variances between age groups with the variances within age groups. When the variances between age groups is much larger than the variances within age groups, significant differences between age groups exist. However, it is not obvious which age groups appear to have different means. To investigate this, post hoc tests have to be carried out. In this study, the Tukey's honestly significant difference (HSD) was used. This test uses the Studentized range statistics to make all pairwise comparisons between age groups and sets the experiment-wise error rate to the error rate for the collection for all pairwise comparisons.

After investigating each relationship separately, the combined effects of age, gender, weight and height on lumbar dynamometry parameters were investigated using stepwise multiple linear regression analysis, with demographic parameters as independent variables and lumbar dynamometry parameters as dependent.

Results

The data for maximum isometric strength parameters (MVC) and maximum velocity parameters against resistances of 25% and 50% MVC, presented in Table 1, show large standard deviations for all isometric strength and velocity parameters. This reflects the large variability in lumbar dynamometry performances in patients with chronic low back pain.

Compared with data of a healthy population [8], the mean maximum isometric strength parameter values of male patients are situated below the 25th percentile and the mean velocity parameter values below the 15th percentile. For female patients, mean isometric strength parameter values are situated below the 10th percentile and mean velocity parameter values below the 5th percentile. This means that velocity is more reduced than strength in patients with chronic low back pain. This is in agreement with literature indicating that velocity parameters are

Table 1 Mean parameter values for the maximum isometric torque and maximum velocity parameters in 45 low back pain patients (MVC maximum isometric torque, MXV 25 maximum velocity against a resistance of 25% of the MVC, MXV 50 maximum velocity against a resistance of 50% of the MVC)

Parameter	Mean (SD)	
	Men	Women
MVC flexion	137.5 (70.47) Nm	46.46 (33.27) Nm
MVC extension	159.9 (78.9) Nm	58.37 (48.57) Nm
MVC left lateral flexion	138.9 (65.6) Nm	57.66 (42.03) Nm
MVC right lateral flexion	142.8 (63.7) Nm	53.7 (37.4) Nm
MVC left rotation	73.3 (40.5) Nm	26.8 (17.5) Nm
MVC right rotation	76.8 (34.7) Nm	31.5 (15.2) Nm
MXV 25 flexion	83.06 (47.49) °/s	38.25 (23.6) °/s
MXV 25 extension	77.75 (43.88) °/s	37.2 (22.22) °/s
MXV 25 left lateral flexion	91.77 (54.00) °/s	43.35 (31.66) °/s
MXV 25 right lateral flexion	91.19 (54.63) °/s	42.99 (27.15) °/s
MXV 25 left rotation	70.8 (41.0) °/s	35.68 (20.92) °/s
MXV 25 right rotation	67.87 (39.9) °/s	36.6 (22.93) °/s
MXV 50 flexion	79.55 (47.02) °/s	40.51 (28.61) °/s
MXV 50 extension	79.82 (49.34) °/s	39.65 (28.87) °/s
MXV 50 left lateral flexion	82.3 (49.83) °/s	35.38 (23.06) °/s
MXV 50 right lateral flexion	81.9 (50.80) °/s	33.78 (22.77) °/s
MXV 50 left rotation	67.45 (39.5) °/s	29.85 (18.39) °/s
MXV 50 right rotation	65.58 (41.06) °/s	28.31 (19.27) °/s

more sensitive. Mean parameter values, presented in Table 1, and results of unpaired *t*-test ($P < 0.05$) show that men performed better than women on all maximum isometric strength and velocity parameters.

Subjects were divided into four age groups: less than 30 years (A30–; 5 patients), 30–39 years (A39; 17 patients), 40–49 years (A49; 15 patients) and older than 50 years (A50+; 8 patients). Mean values show an increase in maximum isometric torque and in maximum velocity against 50% MVC from the group A30– to the group A39, but not for velocity parameters against 25% MVC. No differences in parameter values are found between the group A39 and the group A49. In contrast to this, the group A50+ shows the lowest scores on all isometric torque and velocity parameters, suggesting a fall in performance around the age of 50 years. ANOVA techniques and post hoc Tukey HSD method show that the differences between the age groups are only significant for maximum isometric torque parameters in flexion and left and right lateral flexion. Patients older than 50 years have significantly lower maximum isometric torque values than patients between 30 and 39 years.

Relationships with weight are positive for all lumbar dynamometry parameters, meaning increased performance with increased weight (Table 2). Correlation coefficients vary from 0.17 to 0.61 for the isometric torque parameters and from 0.31 to 0.45 for the velocity parameters. The correlation coefficients are found to be significant ($P < 0.05$) for all velocity parameters and for all iso-

Table 2 Correlation coefficients (*R*) for the relationships between weight, height and lumbar dynamometry parameters (*n* = 45)

Parameter	Weight <i>R</i> (<i>P</i> -value)	Height <i>R</i> (<i>P</i> -value)
MVC flexion	0.61 (0.000)	0.59 (0.000)
MVC extension	0.46 (0.001)	0.51 (0.000)
MVC left lateral flexion	0.17 (0.272)	0.21 (0.159)
MVC right lateral flexion	0.58 (0.000)	0.59 (0.000)
MVC left rotation	0.55 (0.000)	0.52 (0.000)
MVC right rotation	0.56 (0.000)	0.53 (0.000)
MXV 25 flexion	0.41 (0.010)	0.58 (0.000)
MXV 25 extension	0.44 (0.005)	0.58 (0.000)
MXV 25 left lateral flexion	0.36 (0.015)	0.48 (0.001)
MXV 25 right lateral flexion	0.37 (0.013)	0.48 (0.001)
MXV 25 left rotation	0.45 (0.005)	0.54 (0.001)
MXV 25 right rotation	0.43 (0.007)	0.51 (0.001)
MXV 50 flexion	0.32 (0.037)	0.54 (0.000)
MXV 50 extension	0.31 (0.047)	0.53 (0.000)
MXV 50 left lateral flexion	0.44 (0.003)	0.51 (0.000)
MXV 50 right lateral flexion	0.39 (0.007)	0.50 (0.000)
MXV 50 left rotation	0.39 (0.012)	0.48 (0.001)
MXV 50 right rotation	0.39 (0.012)	0.49 (0.001)

metric torque parameters, with the exception of isometric torque in left lateral flexion.

Relationships with height are positive for all lumbar dynamometry parameters, meaning the taller the subject the better the performance (Table 2). Correlation coefficients vary from 0.21 to 0.59 for the isometric torque parameters and from 0.48 to 0.58 for the velocity parameters. The correlation coefficients are found to be significant ($P < 0.05$) for all velocity parameters and for all isometric torque parameters, with the exception of isometric torque in left lateral flexion.

Figure 1 shows some examples of the relationships between weight, height and lumbar dynamometry parameters. The above-mentioned results indicate significant

relationships between gender, height, weight and all lumbar dynamometry parameters, between age and three of the six isometric torque parameters, but not between age and maximum velocity parameters.

As a next step, the study investigates which demographic parameters amongst gender, age, weight and height are most important in relation to lumbar dynamometry parameters in LBP patients. This was investigated using stepwise multiple linear regression analyses, with demographic parameters as independent variables and lumbar dynamometry parameters as dependent. A stepwise multiple linear regression analysis requires: linearity of the relationship between the demographic parameters and lumbar dynamometry measurements, normality of the dependent variable (lumbar dynamometry parameters) for each value of the independent variable (demographic parameters) and similarity of variance in the subgroups. The requirements of linearity and normality were satisfied in all cases. Similarity of variances in the subgroups was not satisfied. A log-transformation was performed for all torque and velocity parameters to meet this requirement.

Table 3 shows that the demographic parameters explain 27–47% of the variance in isometric torque parameters and 19–25% of the variance in maximum velocity parameters. Gender is related to all isometric torque parameters, except the isometric torque in left lateral flexion. Men show higher performances than women. The percentage of explained variance by gender varies from 6% for maximum isometric strength in flexion to 37% for maximum isometric strength in extension.

Age is negatively related to maximum isometric torque parameters in extension and left rotation. However, the additional percentages of explained variance by age after gender are only 6% and 7% respectively.

Weight is positively related to maximum isometric torque parameters in right lateral flexion and right rotation. The additional percentages of explained variances by weight after gender are 6% and 5% respectively.

Height is positively related to maximum isometric torque parameters in flexion and left lateral flexion and to all velocity parameters in all planes of movement. The percentages of explained variance of the maximum isometric torque parameters are 41 and 27% respectively.

Fig. 1 Examples of scatterplots showing the relationships between lumbar dynamometry parameters and weight (A) and height (B)

Table 3 Results of multiple linear regression analysis for the lumbar dynamometry parameters MVC, MXV 25 and MXV 50 in all six directions, against the demographic parameters age, gender, weight and height, showing percentage explained variance (r^2) for each parameter^a. If more than one parameter is presented, the first parameter is the most important one and the r^2 in parentheses represents the percentage explained variance by both parameters. (^a R^2

Movement direction	MVC	MXV 25 against	MXV 50 against
Flexion	Height $r^2 = 0.41^1$ ($r^2 = 0.47$) Gender $r^2 = 0.06$	Height $r^2 = 0.25$	Height $r^2 = 0.22$
Extension	Gender $r^2 = 0.37$ ($r^2 = 0.43$) Age $r^2 = 0.06$	Height $r^2 = 0.20$	Height $r^2 = 0.19$
Left lateral flexion	Height $r^2 = 0.27$	Height $r^2 = 0.20$	Height $r^2 = 0.20$
Right lateral flexion	Gender $r^2 = 0.35$ ($r^2 = 0.41$) Weight $r^2 = 0.06$	Height $r^2 = 0.21$	Height $r^2 = 0.23$
Left rotation	Gender $r^2 = 0.30$ ($r^2 = 0.37$) Age $r^2 = 0.07$	Height $r^2 = 0.22$	Height $r^2 = 0.21$
Right rotation	Gender $r^2 = 0.34$ ($r^2 = 0.39$) Weight $r^2 = 0.05$	Height $r^2 = 0.19$	Height $r^2 = 0.22$

The percentages of explained variance of the maximum velocity parameters lie between 19 and 25%.

Discussion

Research into the relationships between lumbar dynamometry performances and multiple demographic parameters has previously been performed using isokinetic devices [3, 9]. However, any comparison of these results to results obtained using an isoinertial device is hampered by various differences between the two devices.

Of the isoinertial lumbar dynamometry parameters, velocity is clinically most relevant because it is the most sensitive parameter. Velocity revealed the most dramatic differences between patients with chronic low back pain and asymptomatic subjects and showed the largest changes due to an intervention [12, 21].

Concerning the torque parameters, which are measurable with both isokinetic and isoinertial devices, the extent to which maximum torque will vary with demographic parameters like weight and height using the two different biomechanical principles of measurement cannot be estimated. On the other hand, relationships with age and gender are less likely to be affected by these differences in principle. The differences between the two devices mean that investigation of relationships with demographic parameters should be conducted separately for each device.

When relationships between gender, age, weight, height and lumbar dynamometry parameters are investigated separately, significant relationships are found for gender and all isometric torque and all velocity parameters. In all

cases, men show higher performances than women. These results are in accordance with those found in previous studies concerning the relationship between gender and lumbar dynamometry parameters [5, 16, 17].

represents the adjusted R^2 . Sample R^2 tends to be an optimistic estimate of how well the model fits the population. The model usually does not fit the population as well as it fits the sample from which it is derived. Adjusted R^2 presented in this Table attempts to correct R^2 to more closely reflect the goodness of fit of the model in the population)

Concerning age, results show significantly lower scores on maximum isometric torque in flexion and left and right lateral flexion for patients older than 50 years than for those aged between 30 and 39 years. For the other maximum isometric torque and all velocity parameters, no two age groups are significantly different from each other at the 0.05 confidence level. Gomez et al. [5] found different results. They found, in a group of healthy subjects, that isoinertial velocity in flexion and extension was related to age, a fall in performance being associated with increasing age. The present study shows the same trend as indicated by the mean values in the study of Gomez et al. [5]; however, in our study these values are not significant. These discrepancies could be due to the fact that Gomez et al. [5] used a lot more subjects in their studies (168 vs 45 in present study). It is also possible that such a fall in performance with increasing age is present in asymptomatic subjects and is less or not present in chronic low back pain patients. Through chronic pain, patients are hampered in their performances of activities, which consequently decreases their physical capacity. Younger patients will experience more problems, and their performance will decrease relatively more because they would normally be acting on a physically higher level. As a consequence of this, the relationship between age and lumbar dynamometry performance is weakened in patients with chronic low back pain.

The results of this study show significant positive relationships for weight and all isometric torque and velocity

parameters, meaning increased performance with increased *weight*. These results agree with those of Gomez et al. [5], who found that isometric torque measures of the B200 correlated 0.42–0.66 with body weight in male and 0.36–0.51 in female healthy subjects. They also noted a significant correlation between all velocity measures and body weight. In contrast Seeds et al. [16] found low correlations between body weight and dynamic torque output in healthy subjects using the Isostation B100, but this correlation increased as the workload generated by the machine increased. They surmised that a stronger correlation between torque and body weight may exist at workloads that maximally challenge the subject, i.e. when testing isometrically. This hypothesis agrees with the results of present study. Kerner and Kurrant [10] found low negative correlations between peak torque and body weight on the Isostation B200. Only seven healthy subjects participated in their study. This small sample size greatly reduces the precision of the correlation coefficients.

Results of the present study show significant positive relationships between *height* and all isometric torque and velocity parameters. A positive relationship means the taller the subject the better the performance. Seeds et al. [16] found weak correlations for peak torque output of flexion/extension in relation to height in healthy subjects when using low workloads, but this correlation increased as the workload generated by the Isostation B100 increased. In contrast, Seeds et al. [17] found for the Isostation B100 in a later study no significant relationship between height and torque parameters in patients with low back pain. Seeds et al. [17] suggested that the differences between their studies were probably due to the fact that, in the latter study, relationships were calculated separately for male and female patients. The reduced sample size reduces the range of values for height and maximum torque and affects the correlation values.

Only 45 patients participated in this study. This relatively small sample size may have consequences for the power of the multiple regression analysis and may reduce the precision. A power analysis programme of Faul and Erdfelder [4] was used to estimate the power of the multiple regression analysis techniques with four predictors when using 45 subjects. Under the assumption that alpha

is equal to 0.05, the power varies from 0.68 to 0.85 for the different velocity parameters and from 0.98 to 0.99 for the isometric torque parameters. Based on this calculation it can be concluded that the power of the regression analysis is good for the isometric torque parameters but only moderate for the isoinertial velocity parameters.

The background to this study was that controlling for demographic parameters reduces the large intersubject variance and thus improves the interpretation of the obtained muscle performance for the clinician. For this purpose the percentage of explained variance was used. The results indicate that 27–47% of the variance in isometric strength and 19–25% of the variance in velocity parameters can be explained by variances in patient age, height, weight and gender. Gender has the largest quantitative effect on almost all maximum isometric strength parameters (percentage explained variance 6–37%) and height has the largest effect on maximum velocity parameters (percentage explained variance 19–25%). Weight and age each contribute only a small amount to the percentage of explained variance in lumbar dynamometry parameters, meaning that these parameters are non-relevant predictors.

In order to decrease intersubject variability and thus facilitate clinical comparison and interpretation of muscle performance, gender must therefore be taken into account when interpreting maximum isometric strength parameters and height when interpreting maximum velocity parameters.

Conclusion

The purpose of this study was to investigate whether controlling for demographic parameters is necessary to reduce the large intersubject variance in isoinertial lumbar dynamometry performances and thus improve the interpretation of the obtained muscle condition. The results show that gender must be taken into account when interpreting the maximum isometric strength parameters and height when interpreting maximum velocity parameters. Weight and age are both non-relevant predictors, and correction for these parameters is not necessary.

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