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Dynamic Back Extension Muscle Performance Test: Normative Data and Factors Influencing Test Performance

Raine Osborne*

Brooks Rehabilitation Clinical Research Center, Jacksonville, FL

***Corresponding author:** Raine Osborne, Brooks Rehabilitation Clinical Research Center, FL, Email: Raine.Osborne@gmail.com

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Abstract

Background: Back muscle performance is important to the care of patients with low back pain. However, the ability to quantify this performance is limited by tests that require expensive equipment, challenging testing positions, or assess isometric endurance. The purpose of this study is to propose a method for dynamically assessing back extensor muscle performance and to establish the normative values for this test in a physically active population not seeking care for low back pain. Factors influencing test results were also investigated.

Materials and Methods: Adult members (age 18 to 65) from local fitness facilities were recruited to perform a one-session repetition maximum testing protocol using the Precor™ back extension 312. In addition to demographic information, participants BMI, physical activity level, history of low back pain, and daily sitting duration were collected. The maximum number of repetitions achieved was recorded and used to establish normative data for this population.

Results: Participants (n = 312) were able to complete 20 repetitions on average (SD ± 9). Physical activity level, BMI, and race were found to influence the number of repetitions achieved. The number of repetitions achieved by decile for the population were also calculated.

Discussion: Current applications of this research may include baseline assessment and progress evaluation for healthy individuals participating in an exercise program. Future research is needed to investigate the utility of the dynamic back extensor test as a screening tool and for clinical use in that care of patients with low back pain.

Keywords: Muscle testing, low back, lumbar spine, back extension, muscle performance

Introduction

Assessment of back extensor muscle performance is important in the treatment and secondary prevention of low back pain (Freeman, Woodham, and Woodham, 2010; Hodges n m,dn.jkf

and Danneels, 2019). However, healthcare providers such as physical therapists lack access to simple, inexpensive tests that provide quantifiable results for determining status and monitoring progress. Access to such test, along with normative data on expected test performance and threshold values for increased risk of low back injury would be useful to develop screening protocols and inform prognostic and discharge decision-making for patients with low back pain.

Current methods for examining back extensor muscle performance include the Biering-Sorensen test, the isolated lumbar extension test, standing isometric trunk extension force against a load cell or transducer, isokinetic dynamometry, and isometric lifting from a semi-crouched position using a dynamometer. However, these tests have limitations such as the need for expensive equipment (e.g., isokinetic dynamometers), are time consuming, and require potentially challenging testing positions for patients (e.g., Biering-Sorensen test and ILEX). In addition, most of these tests assess isometric performance of the back extensor muscles as opposed to a dynamic flexion and extension of the spine similar to what occurs during performance of daily activities such as bending and lifting. Prior studies have demonstrated limitations in the ability to extrapolate isometric testing to dynamic performance.

Less commonly, dynamic back muscle performance has been investigated using a common piece of gym equipment, the Roman Chair (Figure 1a). Udermann, Mayer, Graves, and Murray (2003) compared both static and dynamic testing using the

Roman Chair to static and dynamic testing using a lumbar dynamometer (MedX, Ocala, FL) and found high correlations for all tests among a group of 8 young, athletic participants. However, the testing position in this study maintained the hips in 0° of flexion which was later demonstrated to allow more hamstring activation compared to a 40° hip flexion position. Larivière et al. (2011) used the 40° hip flexion position on the Roman Chair to test back muscle performance in 16 healthy participants and 18 participants with nonspecific chronic low back pain all between the ages of 20 to 55. Results from the study indicated that during a dynamic repetition maximum fatigue test, muscle activity was initially stronger in the lower portions of the back extensor muscles and switched to the upper portions as participants fatigued. This shift in muscle activity was attributed to participants altering how they flexed the spine, increasing upper trunk flexion and decreasing lower trunk flexion as the lumbar portion of the back muscles fatigued. While this limitation is relevant to specific testing of the lumbar portions of the back extensors, bending and lifting activities engage all portions of the back extensors making performance testing of the entire chain of back extensor muscle potentially useful.

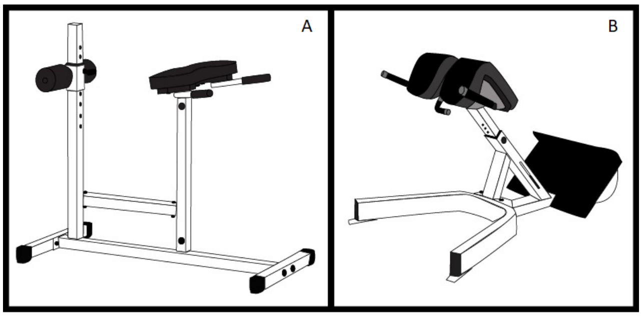

Figure 1. Back extension devices

Our study aimed to resolve some limitations in current methods for assessing back extensor muscle performance by investigating an inexpensive and easy to perform dynamic back extension test (D-BET). This study generated normative data for the D-BET and identified factors that influence test performance, providing a foundation for future research investigating the clinical utility of the D-BET.

Materials and Methods

Sample

Recruitment targeted physically active adults (age 18 to 65) who were not currently seeking care for LBP. Participants were recruited from local YMCA fitness facilities and screened for conditions that could negatively impact participant safety or test performance (uncontrolled hypertension, osteoporosis, cancer, herniated lumbar disk or prior surgery in the lumbar spine, and hamstring strain in the last 12 months). Participants were informed about the study's purpose and procedures prior to signing the consent document. The study procedures were reviewed and approved by the University of North Florida Institutional Review Board (IRB# 1358380-6).

Procedures

We selected the Precor™ Back Extension 312 (Figure 1b) for the D-BET because of the ease of participant positioning, similarity of the positioning to the 40° hip flexion position from prior Roman Chair studies, and because extended padding on the front of the machine provides a consistent target for standardizing trunk flexion. Eligible participants were fit to the device by adjusting the device height so the top of the thigh pads were just below the anterior inferior iliac spines (ASIS) of the participant's pelvis. Participants were instructed on proper performance of the D-BET, which consisted of crossing the arms over the chest with fingertips touching the opposite clavicle and performing a curl-down (segmental spinal flexion) motion until their elbows touched the pads on the equipment as close to their ASIS as possible (see video in supplemental materials). This curl-down maneuver and standardized target were designed to maintain a consistent contribution from all portions of the back extensor muscles throughout the testing procedure. Speed was controlled using a metronome set at 60 beats per minute with participants performing 2 beats for each flexion and 2 beats for each extension of the spine. Participants performed several practice repetitions until the investigator confirmed proper performance. Participants then rested for 2 minutes to allow for recovery before beginning the test. After the rest, participants performed one set of as many repetitions as possible. During the test, one investigator provided feedback to maintain proper speed and form while another investigator counted repetitions. The test ended when the participant stopped due to fatigue or pain, or when the examiner noted the participant was unable to maintain speed, form, or full range of motion. Repetition number and the presence and location of any pain or discomfort post exercise was recorded.

Questionnaire

Participants completed a brief survey to identify factors that may influence back muscle performance. In addition to demographic questions, the questionnaire asked for height, weight, history of low back pain (LBP), physical activity level, and amount of time spent sitting per day.

Height and weight were used to calculate body mass index (BMI). History of LBP was classified as any prior episode of LBP resulting in missed work or change in daily activities. Participants with LBP in the last 6 months were asked to rate their current level of pain and the maximum and minimum pain in the last 6 months on a 0-10 pain rating scale. Physical activity level was assessed with the U.S. Department of Health and Human Services (HHS) guideline of ≥ 75 minutes of vigorous or 150 minutes of moderate physical activity per week (U.S. Department of Health and Human Services, 2018). Daily sitting duration was categorized as the usual amount of sitting per day (1-3 hours, 3-6 hours, 6-9 hours, 9-12 hours).

Statistical analysis

Descriptive data were examined to determine demographic characteristics and frequency of D-BET repetitions. Univariate analyses were used to examine the distribution of the dependent variable, as both unaltered and normalized through log-transformation. Bivariate analyses were performed to identify participant characteristics associated with D-BET repetitions. We used t-Tests and analysis of variance (ANOVA) models with Tukey's pairwise comparisons to compare mean D-BET repetitions between categorical variables. We also evaluated interactions of race, gender and age with all other predictor variables. To identify factors associated with D-BET repetitions, multivariable linear regression models were developed and compared. A full model that included demographic characteristics, variables that had a statistically significant bivariate association ($p < 0.05$) and potential interactions was developed to predict D-BET repetitions. We also developed a full model to predict log-transformed D-BET repetitions. A backward elimination method with $\alpha = 0.05$ was used to determine the significant variables to remain in the final model. SAS 9.4 for Windows (Cary, NC) was used for this analysis.

Results

Statistical analysis was performed using data from 312 of 319 (98%) of participants with no missing data.

Characteristics

Characteristics and physical activity behaviors of participants are presented in Table 1. The age of participants ranged from 18 to 65 years, with a mean of 36 years. The majority were male (56%, n = 176), described themselves as White (67%, n = 208), and were of healthy weight with a body mass index <=25 (47%, n = 155). History of low back pain was reported by 26% (n = 82) of the study participants. Among the 312 participants, obesity (BMI >30) was more prevalent among Black/African American participants (34.8%, n = 16) compared to White (13.9%, n = 29), Asian (6.5%, n = 2), and other race (22.2%, n = 6) participants ($\chi^2=22.4$, p=0.001). The majority of participants (93%, n = 289) met recommendations for weekly physical activity and reported sitting for less than 6 hours per day (55%, n = 171).

Characteristic		N(%)	Median	Mean (SD)	P Value
Age (years)					0.49
	<=30	123 (39)	20.0	20.4 (8.7)	
	30-39	83 (27)	20.0	20.7 (8.6)	
	40-49	48 (15)	18.0	19.9 (7.9)	
	50-59	37 (12)	20.0	21.9 (10.0)	
	60-69	21 (7)	22.0	23.8 (13.6)	
Gender					0.71
	Male	176 (56)	20.0	21.0 (10.2)	
	Female	136 (44)	20.0	20.6 (8.0)	
Race					
	African American / Black	46 (15)	14.0	16.8 (9.4)	0.02
	White	208 (67)	21.0	22.0 (9.3)	
	Asian	31 (10)	20.0	20.6 (7.3)	
	Other	27 (8)	18.0	18.5 (7.0)	
BMI					
	Healthy weight (<=25)	155 (47)	21.0	23.2 (10.2)	<0.0001
	Overweight (>25-29.9)	104 (36)	19.5	19.6 (7.3)	
	Obese (>30)	53 (17)	15.0	16.4 (6.6)	
Self-reported history of low back pain					
	Yes	82 (26)	21.0	21.7 (9.5)	0.29
	No	230 (74)	20.0	20.5 (9.0)	
Self-reported physical activity meets recommendations (weekly ≥ 75min vigorous or 150 min moderate)					
	Yes	289 (93)	20.0	21.2 (9.2)	0.01
	No	23 (7)	16.0	16.1 (7.2)	
Self-reported hours sitting per week					
	1-3 hours	74 (24)	19.5	20.7 (9.5)	0.30
	3-6 hours	97 (31)	22.0	22.0 (9.0)	
	6-9 hours	107 (34)	19.0	19.6 (7.9)	
	9-12 hours	34 (11)	18.0	21.5 (11.8)	

Table 1. Participant characteristics and differences in lumbar repetitions (N = 312).

Lumbar repetitions

We found considerable variability in the total number of D-BET repetitions among the participants in this study. On average, participants completed 20 repetitions (SD = 9 reps) during their session, with the total number of repetitions ranging from 6 to

57 repetitions. The number of repetitions by decile are presented in Table 2. Univariate analysis revealed a positively skewed distribution (skewness = 1.2) with a median of 20 repetitions (IQR =14 to 25). Skewness was improved with log transformation of repetition count (skewness= -0.06, median=3.0, IQR =2.6 to 3.2).

Repetitions by Decile	
Percentile	**Repetitions**
90th	33
80th	27
70th	23
60th	22
50th	20
40th	17
30th	15
20th	13
10th	11

Table 2. Number of repetitions performed by decile

The results of bivariate analysis of participant characteristics with lumbar repetitions are shown in Table 3. On average, participants with a healthy weight BMI completed 23.2 repetitions (SD=10.2) during their session, while participants with an overweight or obese BMI completed fewer repetitions (19.6 and 16.4, respectively, p<0.0001). Participants meeting physical activity guidelines completed significantly more repetitions on average compared to those not meeting the guideline recommendations (21.2, SD = 9.2 and 16.1, SD = 7.2, respectively, p = .01). African American/Black participants and other race groups completed a mean of 16.8 and 18.5 repetitions respectively, while Asian and White participants completed a statistically greater number of repetitions on average (20.6 and 22.0, respectively, p = .02). Body mass index, Race, and physical activity were also significantly associated with repetitions when transformed on the log-scale to account for data skewness (p<0.0001, p=0.0001, p=0.0039, respectively). Although not statistically significant, participants in the oldest age group averaged the greatest number of lumbar repetitions (mean=23.8, p=0.49). Age, gender, history of low back pain, and hours sitting per day were not associated with D-BET repetitions.

Characteristic		Estimate (95% CI)	P Value
Intercept		20.25 (16.5, 24.0)	<0.0001
Race			
	White	Ref	
	African American / Black	-3.17 (-6.01, -0.33)	0.029
	Asian	-1.75 (-4.98, 1.49)	0.277
	Other	-3.47 (-6.92, 0.03)	0.059
BMI			
	Healthy weight (<=25)	Ref	
	Overweight (>25-29.9)	-3.55 (-5.69, -1.40)	0.0012
	Obese (>=30)	-6.06 (-8.80, -3.31)	<0.0001
Self-reported physical activity meets recommendations			
	No	Ref	
	Yes	4.04 (0.35, 7.74)	0.032

Table 3. Participant characteristics and behaviors associated with lumbar repetitions (N=312)

The boxplot diagram in Figure 2 presents a visual representation of the relationship between D-BET repetitions with BMI and physical activity. We observed lumbar repetitions decreased with increasing BMI independent of physical activity. Obese participants thus had the fewest repetitions completed but an interaction between these factors did not reach significance (p > .05).

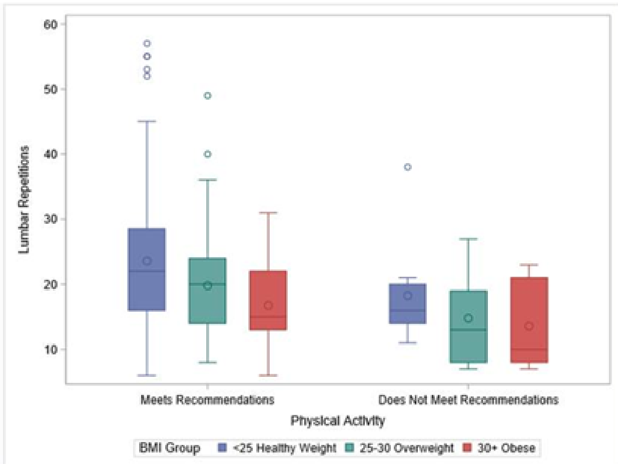

Figure 2. Distribution of lumbar repetitions, by BMI and physical activity (N=312)

Table 2 shows the results from multivariable linear regression examining the relationship between lumbar repetitions, participants' characteristics, and physical activity behaviors. In the final model, participants with an overweight or obese BMI completed fewer repetitions compared to their healthy weight counterparts (β =-3.60, 95CI =-5.76, -1.45; β =-5.98, 95CI =-8.73, -3.23, p < .01). After adjusting for BMI and physical activity, African-American participants completed significantly fewer repetitions compared to White participants (β = -3.17, 95CI = -6.01, -0.33; p = .03). Less physically active participants completed 4 fewer repetitions on average (β =-4.04, 95CI =-0.35, -7.74, p = .03). Similar results were observed when repetitions count was normalized through log-transformation (data not shown).

Discussion

This study introduces a simple, inexpensive test for the dynamic assessment of back extensor muscle performance and establishes normative data for use in future research. In addition, our analysis of factors influencing test performance provides useful information for comparison of individual test results to a reference population. Future studies should compare these findings with results from a population of patients seeking care for low back pain to evaluate the clinical utility of the D-BET.

Normative data and reference ranges

Results from this study indicate active adults ages 18-65 not currently seeking care for low back pain complete 20 repetitions on the D-BET on average, with 68% of similar individuals completing between 11 and 29 repetitions. The considerable variability in test performance makes interpretability of an individual's test results challenging. Test administrators can improve this interpretability by identifying the nearest decile associated with the number of repetitions an individual achieves. This allows for a greater level of discrimination between scores falling within the normal range. For example, an individual who performs 13 repetitions and an individual who performs 23 repetitions are both within the 1 standard deviation normal range, but the first falls within the 20th decile while the latter is within the 70th decile. Future research should identify if D-BET decile ranking is related to important clinical factors such as risk of developing low back pain or recovery from an episode of low back pain

Factors in luencing test performance

Our findings that BMI, level of physical activity, and race have a significant influence on the number of D-BET repetitions are also important to consider when interpreting individual test results. Using physically active White individuals with a BMI < 25 (normal weight) as a reference population, our results indicate that less physically active individuals perform 4 fewer repetitions on average, while those with a BMI between 25.0 and 29.9 (overweight) or over 30.0 (obese) perform around 3 and 6 fewer repetitions on average respectively. Based on these findings, a D-BET result of 15 repetitions may be expected for an inactive and overweight individual while the same result may indicate unexpectedly low performance for an active normal weight individual. The reduced number of repetitions associated with higher BMI and less physical activity are intuitive and aligns with prior research (Chen et al, 2009; Teichtahl et al, 2015). However, the reason for the observed decrease in average number of repetition among non-White participants, particularly African-American/Black participants, is less clear. The clinical significance of these results is unknown at this time and should be the focus of future research.

Participants' gender, age, daily sitting duration, and history of low back pain did not have a significant effect on D-BET performance. The lack of difference between males and females is consistent with prior research demonstrating increased fatigability in females for isometric but not for dynamic muscle performance (Clark, Manini, The´, and Ploutz-Snyder, 2003; Hunter, 2016). Our finding of a non-significant but higher mean number of repetitions achieved by the older participants in our study stands in contrast to prior studies indicating a decrease in muscle performance with age in individuals under age 65 (Adedoyin et al, 2011; Singh, Bailey, and Lee, 2013; Verbrugghe et al., 2020). While the exact reasons for this finding are unclear, one possibility may be that our recruitment of YMCA members resulted in a sample of older adults representing a more fit portion of age-matched peers in general population compared to the younger adult sample. Our finding of no effect from daily sitting duration is also in contrast to findings from prior studies (Keevil et al., 2016; Park and Bae, 2013). However, the high level of physical activity in our sample may have counteracted the negative effects of prolonged sitting (Ekelund et al., 2016). Our analysis of the effects of LBP on D-BET performance was limited to comparing only those reporting any history of LBP to those without a history of LBP due to an insufficient number of participants reporting LBP in the last 6 months. The similarity in performance between those with and without a history of LBP is encouraging. This may represent a population of individuals that have recovered from prior LBP, indicating that patients with LBP can achieve similar performance on the D-BET to healthy controls. Future research demonstrating a significant decrease in D-BET performance among individuals with LBP combined with changes in D-BET performance associated with clinical recovery are needed to test this hypothesis.

Limitations

As with any study, ours contains several limitations that should be acknowledged. First, the study population only included those up to age 65, excluding a large population of healthy, active individuals and limiting the generalizability of our results. We recognize the lack of inclusion of older adults in research trials as an important issue that affects a wide range of research areas. We made this decision out of an abundance of caution for the safety of participants performing this new test and the lack of sufficient funding to assess bone health in this population. We made similar exclusions for individuals with other conditions (e.g. prior herniated disc) for the same reasons. The lack of adverse events occurring in this study provides evidence that the testing procedure is generally safe. Future studies with clinical populations, including these higher risk populations, would add to the current evidence.

Second, we had to make occasional adjustments to the thigh pad height due to large abdominal girth limiting the participants' ability to complete the full range of motion. We lowered thigh pad height in these situations to allow more room for the abdomen, which may have reduced stability of the pelvis allowing for an anterior tilt and potentially increased hamstring activation. Although we monitored for this substitution and did not visibly see it occur, we cannot rule out this possibility. The effect of this adjustment on test performance is unknown and occurred in less than 10 participants. We feel confident in recommending this minor adjustment as an acceptable modification to th e D- BET procedures as ne eded without affecting interpretation of results.

Third, our study did not include biomechanical analysis of muscle function or body segment movements. While our testing procedures were developed from prior studies using similar testing methods, we did have several modifications (e.g. use of a spine curl down to standardize trunk motion) that warrant further validation.

Finally, the clinical relevance of these findings is still unknown. We have established normative data for a healthy, active population but we have not established if these values differ from a population of individuals seeking care for low back pain. Any claims related to injury or recovery based on these data would be premature.

Clinical implications

This study introduces a novel method for assessing dynamic muscle performance of the back extensors that is easy to perform and requires only simple and inexpensive equipment, making it more accessible to clinicians than current methods. Furthermore, the normative data and factors influencing test performance facilitates interpretation of test results relative to a population of physically active individuals not seeking care for LBP. At present, physical therapists and others with knowledge of physical performance testing can use the D-BET to perform baseline assessments and monitor progress for healthy individuals participating in an exercise program. Future research will determine the effectiveness of D-BET as a screening test for risk of low back injury as well as a clinical test to quantify impairment and monitor improvements in back extensor muscle performance.

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