1   **Performance based on sEMG activity is related to psychosocial components: differences**

2   **between back and abdominal endurance tests.**

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1 **Introduction**

2 Physical and psychosocial deconditioning is common in patients with chronic LBP [Brox et al, 2005;

3 Frost et al, 1998]. Research showed that the clinical evolution and prognosis of LBP is influenced by

4 psychosocial factors such as pain related fear [Crombez et al, 1999; Sullivan et al, 2009], pain

5 catastrophizing [Burton et al, 1995; Meyer et al, 2009], pain and functional self-perceived disability

6 [Vlaeyen & Linton, 2000; Thomas & France, 2008], self-reported health [Ahrens et al, 2010] and

7 depression [Ryan et al, 2010]. All these psychosocial influences make it hard to ensure that physical

8 measurements in patients with persistent non-specific LBP provide an accurate representation of the

9 real physical condition.

10 Biering Sorenson [Biering Sorenson, 1984] developed a test to measure back muscle fatigability and

11 demonstrated that a shorter position-holding time during this test predicted LBP within the next years

12 [Demoulin et al, 2006]. However, a clear influence of psychosocial factors on the endurance time of

13 the Biering-Sorenson test (B-S test) was demonstrated, in healthy subjects as well as in patients with

14 chronic LBP [Larivière et al, 2010; Coorevits et al, 2008]. In order to obtain a more objective

15 measurement of the intrinsic muscle fatigue, a measure for the decrease of the median frequency

16 during static submaximal testing, recorded by surface electromyography (sEMG), can be used

17 [Coorevits et al, 2008]. A regression coefficient of the median frequency slope towards lower

18 frequencies can be used as a fatigue index for the investigated muscle. This regression coefficient is

19 often normalized by the intercept, which is the crossing point of the slope and the Y-axis [Konrad,

20 2005]**.** A combination of the use of the regression coefficient of the median frequency, time to

21 exhausting and self-reporting questionnaires, could be useful to understand the different influencing

22 factors on physical performance.

23 In contrast to the almost systematic use of the B-S test and its modified versions to analyze back

24 muscle endurance, much more variation in position and procedure is observed in abdominal

25 endurance tests. Brox et al. [2005] utilized a dynamic abdominal endurance test to demonstrate that

26 deconditioning (deterioration of impairment and disability) was more related to psychological

27 measures and physical measures of abdominal and back muscle endurance than to general

1 cardiovascular fitness (estimated by a submaximal bicycle ergometer test). However, static endurance

2 tests are preferred since variation in muscle length throughout the test can alter the frequency content

3 of the EMG signal [Mannion et al, 1996; Sparto et al, 1999].

4 In conclusion, research on the relation between psychosocial deconditioning and physical

5 performance is scarce and often lacks standardized and specialized physical testing or sufficient

6 patients. Therefore, the aim of the present study was to investigate the influence of psychosocial

7 components on the duration of standardized back and abdominal static endurance tests in patients

8 with persistent non-specific LBP. Determining good performance may lead to a better understanding

9 of factors that make patients perform less than they physically can during these tests. The hypothesis

10 was that underperformance during back and abdominal endurance tests in patients with persistent

11 non-specific LBP is influenced and may be predicted by psychosocial components.

12 **Materials and Methods**

13 *Patients*

14 Three-hundred and thirty-two patients (291 men and 41 women; military and civilian employees) from

15 19 to 63 years old with persistent non-specific LBP, with or without leg pain, were included in this

16 study after screening by a medical doctor specialized in physical medicine at the Military Hospital

17 Queen Astrid in Brussels. When needed additional investigations were performed to assure that no

18 identifiable specific anatomical or neurophysiological causative factors were present. Pregnant

19 women, patients with previous spinal surgery, nerve root entrapment with neurological deficit, patients

20 with specific LBP diseases and patients with a BMI ≥ 33 were excluded from this study. Study

21 population characteristics are shown in Table 1. The study was approved by the Ethical Committee of

22 the Ghent University.

23

24 *Psychosocial assessment questionnaires*

25 All subjects received self-report questionnaires before performing physical tests. General questions

26 related to the sociodemographic status and characteristics of their LBP were registered. Several

1 validated questionnaires were used as a measure of physical and/or psychological influence of the

2 LBP on daily life. A numerical scale was used to indicate the average pain over the last week. Pain

3 Catastrophizing was measured by the Pain Catastrophizing Scale (PCS) and its three subscales

4 (rumination, magnification and helplessness) [Sullivan et al, 1995]. The Hospital Anxiety or Depression

5 Scale (HADS) [Zigmond & Snaith, 1983] determined the levels of anxiety and depression that a patient

6 was experiencing. The Distress Risk Assessment Method (DRAM) consisting of the Modified Somatic

7 Perceptions Questionnaire (MSPQ) [Mannion et al, 2011; Main, 1983] and the Modified Zung

8 Depression Index (MZDI) [Mannion et al, 2011; Zung et al, 1965] were used as screening tools for

9 depression and somatic pain respectively. The Short Form Health Survey (SF-36) [Ware & Gandek,

10 1998] and its different subscales gave a general measure of health, both mental and physical

11 components. Depending on the mother tongue, the participants filled in the questionnaires in Dutch or

12 French (validated versions).

13

14 *Physical Assessment – endurance tests*

15 An isometric endurance test for the abdominal muscles (AE test) [Stevens et al, 2008] was performed

16 (Figure 1). The patient was seated on a bench in a straight-knee position, with the trunk unsupported

17 at a 45-degree angle. The hands were placed on the shoulders with the arms flexed alongside the

18 trunk. Neutral position of the head and lumbar spine was respected.

19 For the evaluation of the isometric endurance of the trunk extensor muscles patients performed a

20 modified version of the B-S test (Figure 2) [Demoulin et al, 2006; Coorevits et al, 2008; Demoulin et al,

21 2013; Stevens et al, 2006]. The patient was lying on a bench in a prone position with the anterior-

22 superior iliac spines at the rotation point of the bench. The lower body was fixed to the table by two

23 straps, one around the pelvis and one on the ankles. The patients had to hold their hands touching

24 their foreheads, with their elbows out to the side and leveled with the trunk. Patients were also

25 instructed to hold their head in a neutral position, and to look downward. The test was started with the

26 upper body in an about 70° downward position so that a concentric contraction of the trunk extensor

27 muscles was needed initially to reach the horizontal position.

1   The patient was asked to isometrically maintain these positions. This was checked by visual

2   evaluation. The time the patient held these positions was recorded. Verbal encouragement was given

3   by the tester during both endurance tests to ensure that the maximal effort was produced by the

4   patient.

5   *EMG recording*

6   sEMG was used to quantify the rate of development of muscle fatigue. After appropriate skin

7   preparation in order to get a good electrode-skin contact and to reduce skin impedance, 8 pairs of

8   circular Ag/AgCl sensor surface electrodes (Ambu® Blue Sensor M, Ambu A/S, Ballerup, DK) were

9   placed parallel to the muscle fibres [Ng et al, 1998], bilaterally, of 2 deep stabilizing and 2 superficial

10   torque producing abdominal and back muscle groups as follows: The inferior fibres of the internal

11   obliques (IO) (midway between the anterior iliac spine and the symphysis pubis, above the inguinal

12   ligament) [Stevens et al, 2008; Van Damme et al, 2012], the external obliques (EO) (15 cm lateral to

13   the umbilicus) [Cholewicki et al, 1997; Hubley & Vezina, 2002], the lumbar multifidus (LMF) (above

14   and below the L5 spinous process, parallel to the line between the posterosuperior iliac spine and the

15   L1–L2 interspinous space) [Danneels et al, 2001; Ng et al, 1997], the thoracic part of the iliocostalis

16   (ICLT) (above and below the L1 level, midway between the midline and the lateral aspect of the body)

17   [Stevens et al, 2008; Van Damme et al, 2012; Danneels et al, 2002]. A reference electrode was placed

18   on the thoracic cage.

19   Electromyographic signals were recorded using an 8-channel sEMG system (Myosystem 2000,

20   Noraxon U.S.A. Inc., Scottsdale, AZ) connected to a computer. The raw sEMG signals were recorded

21   at a sampling rate of 1000Hz, amplified (overall gain 1000, common mode rate rejection ratio 115 dB),

22   filtered to produce a bandwidth of 10 – 500 Hz and analog digital conversion (12-bit resolution) was at

23   1000 Hz. Each recorded sEMG signal that was stored on the computer was divided in intervals of 5 s.

24   The median frequency (MF) of the sEMG power spectrum was calculated at each 5-s interval with

25   Fast-Fourier Transform algorithms using the Noraxon MyoResearch software v2.11. During a

26   sustained isometric contraction of the muscles, the MF spectral shifts indicate local muscle fatigue and

27   decrease over time [Sung et al, 2009]. The MF was defined as the frequency that divided the

1   spectrum into two equal areas. Finally, linear regression analyses were performed on the calculated

2   MF's as a function of time. The initial MF (MF_{init}) was defined as the intercept of the regression line

3   and the MF slope (MF_{slope}) was determined as the slope of the regression line. MF_{slope} was normalized

4   to MF_{init} [Biering Sorenson, 1984], to deal with inter subject and inter location differences in

5   subcutaneous tissue layers. The MF_{slope}, normalized to MF_{init}, gave a measure of fatigability for each

6   recording site for each individual [Mannion et al, 2011; Coorevits et al, 2008].

7

8   *Data analysis*

9   The outcome of each questionnaire was calculated following the instructions of the original designers.

10   SPSS 21.0 was used for statistical analyses. Statistical significance was accepted at the 5% level.

11   Patients were dichotomized as underperformers and performers, by comparing their real endurance

12   time, to the expected time of endurance derived from the normalized MF_{slope} (NMF_{slope}). This was done

13   for the B-S test and the AE test separately. The NMF_{slope} [Coorevits et al, 2008] provided a measure of

14   fatigability for each muscle on both sides, for each subject. The endurance time was regressed on the

15   NMF_{slope} for the most fatigable region of the LMF during the B-S test and for the most fatigable region

16   of the IO during the AE test. The deep stabilizing muscles were selected because, in this group, they

17   showed generally a steeper slope than the superficial torque-producing muscles. Endurance appears

18   to be limited by the most fatigable region of a muscle group [Mannion & Dolan, 1994]. Stepwise

19   multiple regression analyses (Probability of F-to-enter ≤0.05; Probability of F-to-remove ≥0.10) were

20   used to determine a linear model for the endurance time of the two endurance tests. The influence of

21   gender on the slope and the intercept of the regression line were analyzed. For this reason, the

22   dummy variable gender and gender*NMF_{slope} were introduced as two extra independent variables into

23   the model. Using the regression equation derived from the group data, the "expected" endurance time

24   for a given subject was determined for both exercises. Depending on whether their real endurance

25   time fell short (a) or was equal to or exceeded (b) the expected time, they were classified as

26   underperformers (a) or as performers (b) for that specific exercise. A similar method was used by

27   Mannion et al. (2011), but in the present model gender was also added in the regression model.

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2 For the AE test and the B-S test separately, independent t-tests were performed to examine the

3 differences between underperformers and performers on the different variables and self-reporting

4 questionnaires. Stepwise multiple regression analysis (Probability of F-to-enter ≤0.05; Probability of F-

5 to-remove ≥ 0.10) was performed using the variables that were found significantly different between

6 the two groups in a bivariate analysis as predictor variables. For the regression analyses, the

7 normality of the errors, independency of the errors and the homoscedasticity assumption were

8 verified.

9

10 **Results**

11 The linear regression analysis for the B-S test (Figure 3) provided two different parallel regression

12 lines, one for each gender. The regression line for the female patients was situated below the model of

13 the male patients. In the AE test no significant differences were found between the regression line of

14 male and female patients. This means that the prediction line (Figure 4) was the same for male and

15 female subjects.

16 *Biering-Sorenson Test*

17 Independent t-tests between the underperformers and performers on the B-S test (Table 2) showed

18 that the mean age ($p=0.007$) and mean BMI ($p<0.001$) of the underperformers were higher than these

19 of the performers. No significant difference was found in hours of sport per week (sport hrs/week)

20 between the two groups ($p=0.988$). The two groups had a similar NMF_{slope} of the LMF ($NMF_{slope}LMF$),

21 but the performers group demonstrated a significantly longer endurance time on the B-S test

22 ($p<0.001$). The scores on some of the subscales of the SF-36 were significantly higher for the

23 performers: Physical Function ($p<0.001$), General Health ($p<0.001$) and total Physical Health

24 ($p=0.046$).

25 Stepwise multiple regression analysis (Table 3) of all the variables that were found significant in

26 bivariate analysis revealed that a greater BMI ($β=-221.748$; $p<0.001$) and lower scores on the Physical

1   Function subscale of the SF-36 (β=355.209; p=0.001) were significant predictors of underperformance

2   on the B-S test. These components explained more than 10% (R^2=0.113) of the variance.

3   *Abdominal Endurance Test*

4   Independent *t*-tests between the underperformers and performers on the AE test (Table 4) showed

5   that the underperformers group of the AE test had a significantly higher BMI (p=0.014). No significant

6   difference was found in sport hrs/week between the two groups (p=0.482). The two groups had a

7   similar NMF_{slope} of the IO (NMF_{slope}IO), but the performers group demonstrated a significantly longer

8   endurance time on the AE test (p<0.001). The underperformers group scored significantly higher on

9   the DRAM MZDI (p=0.018) and on the PCS scale (p=0.020), as well as on two of its subscales:

10   magnification (p=0.025) and helplessness (p=0.012). This group showed also significantly lower

11   scores on the SF-36 and some of its subscales: General Health (p=0.009), Social Functioning

12   (p=0.048), Role Emotional (p=0.008), total Physical Health (p=0.25) and total Mental Health (p=0.006).

13

14   Stepwise multiple regression analysis (Table 5) of all the variables that were found significant in

15   bivariate analysis revealed that a higher BMI (β=-2748.282; p=0.005) and a lower score on the total

16   mental health subscale of the SF-36 (β=547.415; p=0.011) were predictive for underperformance on

17   the AE test. These components explained more than 4% of the variance (R^2=0.049).

18   **Discussion**

19   The present study examined the relationship between psychosocial components and

20   underperformance -performance less than expected- on abdominal and back muscle endurance tests

21   in patients with persistent non-specific LBP. The main findings were that underperformance on back

22   muscle endurance tests was more likely to be influenced by physical components (self-reporting on

23   physical health), whereas abdominal muscle endurance tests seemed more affected by psychosocial

24   components (self-reporting of mental health). Performing less than expected as in underperformance,

25   does not necessarily involve low performance, but may even present high performance in well-trained

26   subjects.

1

Back muscle endurance

For the B-S test underperformers had statistical significant lower scores on different subscales of the SF-36: Physical Function, General Health and total Physical Health. All these scales reflect a physical component. So, we could suggest that more negative perceptions of physical health could induce underperformance on the B-S test.

The results described above are in line with observations in elderly patients with chronic LBP [Ledoux et al, 2012]. Functional capacity, measured by endurance and peak torque during prone and side bridge positions, was very much dependent on physical components (physical activity and disability levels), and not on psychosocial components as depression scores or pain catastrophizing. In the current study baseline physical activity, reported in sport hrs / week was not different between the group underperformers and good performers, but a more detailed questioning about physical activity could have given more information. Disability levels in se were not reported in the current study, but reporting on physical health was significantly different between the two groups in the B-S test. Demoulin et al. [2013] did not find any association between endurance time on the B-S test and pain-related fear measures, but no subdivision was made between performance groups. Mannion et al. [2011] found that underperformers on the B-S test had more negative back beliefs, greater psychological disturbance, greater catastrophizing and lower exercise self-efficacy compared with the performers. In contrast to the results of the present study, the underperformers showed significant greater catastrophizing and psychological disturbance. Larivière et al. [2010] suggested that pain catastrophizing is related to outcome on the B-S test. These different results might be explained by the population characteristics. In contrast to all active working patients in the present study, Larivière et al. [2010] observed a population in which 10 of the 27 patients were not at work (7 due to back problems). In the study of Mannion et al. [2011] the group symptoms were similar to the present group, but there were a lot more female subjects (57%). In contrast to the present study, Mannion et al. [2011] did not take gender into account while making the subdivisions in underperformers and performers group. However, several studies demonstrated a clear gender difference in muscle

1 fatigability during the B-S test. Kankaanpää et al. [1998], for example, demonstrated sex differences in

2 paraspinal muscle fatigability during the B-S test and explained this by gender differences in muscle

3 anatomy and physiology. Therefore, gender cannot be thought away in determining the performance

4 group. In addition, gender differences have been found consistently in catastrophizing, with women

5 reporting significantly higher scores than men on the PCS [D'Eon et al, 2004; Thorn et al, 2004]. In

6 several studies, performance was evaluated by a Functional Capacity Evaluation (FCE) or other

7 physical tests and no strong relationship was found between the FCE-physical outcome and

8 psychological factors [Schiphorst et al, 2008; Reneman et al, 2007; Smeets et al, 2007]. This is in line

9 with the results found in the present study, although the physical tests were very different.

10 *Abdominal muscle endurance*

11 Underperformers on the AE test had significantly higher scores on the DRAM, the MZDI and on the

12 PCS and two of its subscales: magnification and helplessness. The SF-36 and some of its subscales

13 (general health, social functioning, role emotional, total physical health and mental health) of this

14 group showed lower scores, indicating more problems with these health components. Patients who

15 were more emotionally distressed and patients with high levels of catastrophizing tended to

16 underperform on the AE test. No studies were found which specifically investigated the relation

17 between underperformance on abdominal muscle tests and psychological distress. Brox et al. [2005]

18 investigated healthy controls and patients with sub-acute and chronic LBP and found that patients with

19 chronic LBP demonstrated significantly higher pain, self-reported functional disability and fear-

20 avoidance and lower abdominal and back muscle endurance times than sub-acute patients. A study of

21 Sullivan et al. [2002] revealed that pain catastrophizing was significantly predictive for low

22 performance on a repeated lifting task in patients with chronic LBP. However, performing less than

23 expected as in underperformance, does not necessarily involve low performance, but may even

24 present high performance in e.g. well-trained subjects.

25 Multiple regression analysis demonstrated that a greater BMI and lower scores on the Physical

26 Function subscale of the SF-36 were significant predictors of underperformance on the B-S test and

27 that a higher BMI and lower scores on the total mental health subscale of the SF-36 were predictive

1 for underperformance on the AE test. It is striking that performance on back muscle endurance tests

2 was more likely influenced by physical components, while the abdominal muscle endurance test

3 seemed more affected by psychological components. Different subjective observations were made,

4 which could explain this discrepancy. Some aspects, typically observed during the AE test, could

5 influence the patient's motivation to perform. In general, subjects reported more pain discomfort during

6 the AE test. The sitting position is for many patients a pain provocative position. Although the neutral

7 position of the back was respected during the AE test, patients did not like to sit in this position and

8 needed a lot more motivation to hold it. Previous research demonstrated that pain catastrophizing is in

9 strong relation with pain [Sullivan et al, 2001]. Catastrophizing, in the absence of pain, is not

10 associated with impaired physical function or with reduced motivation to perform physical maneuvers.

11 However, under conditions where movement is associated with pain, catastrophizing appears to

12 contribute to a reduction in physical outcome [Sullivan et al, 2002] and this could explain

13 underperformance. In contrast to the lumbar extension control position during the B-S test, the

14 abdominal endurance demanded more control to avoid lumbar flexion. Higher catastrophizing and

15 emotionally distressed patients may fear flexion positions more than extension postures. Flexion-

16 related pain disorders are the most common disorders observed in clinical practice [O'Sullivan, 2000].

17 In the sitting flexion endurance test, patients also experienced vibrations in the abdominal muscles;

18 these vibrations were generally not observed during the B-S test. Due to the uncomfortable sensation

19 of these vibrations, the patient's performance could have been disturbed. In addition, the visual focus

20 was also very different between the two endurance tests. During the B-S test, the patients' vision was

21 orientated to the ground, which created less visual disturbance in comparison to the view of the test

22 environment, equipment and testers during the AE test. Highly test-anxious persons often divide their

23 attention between task-irrelevant and task-relevant variables and become more distractible, whereas

24 low-test anxious persons focus their attention more fully on the task [Pijpers et al, 2005; Eubank et al,

25 2000]. This could explain why patients who were more psychologically distressed tend to

26 underperform on the AE-test compared to subjects who were not psychologically distressed, and

27 could also clarify why we did not find such a difference in the B-S test. However, the relative shift in

28 attention away from environmental cues, and towards internal monitoring of feelings, thoughts and

1   movements – which is more likely to happen in the B-S-test - has also been demonstrated to have a

2   detrimental effect on motor performance especially in anxious people [Maxwell et al, 2000; Janelle,

3   2002].

4   Patients who are more psychologically distressed could be more influenced by all these different

5   factors. Further exploration of the causes of this statistical difference between the AE test and the B-S

6   test is needed.

7   Although the results of the multiple regression analyses were in accordance to the clear statistical

8   significant differences between the group of the underperformers and the good performers, the effect

9   sizes of the regression analyses were small. Only about 10% in the B-S test and 4% in the AE test of

10 the variance could be explained by the defined variables. In sociological and biological measurements

11 high percentages are almost never achieved, however it is often possible to identify about 25% of the

12 variance of a relationship [Botz & Doering, 2002]. This was not achieved in the present study.

13 However, interpretation of linear regression analysis is not straightforward [Schneider et al, 2010] and

14 some statisticians believe that being able to improve an outcome by 4% can be clinically useful.

15 In previous research, BMI was observed as a significant predictor of endurance time in the B-S test

16 [Mbada et al, 2009]. This could be explained by the association between BMI and the rate of MF

17 decrease during this test. A higher BMI was shown to create a greater fatigability and a lower

18 endurance time of the paraspinal muscles [Kankaanpää et al, 1998]. The present study examined this

19 more thoroughly, and found in addition a direct association between BMI and underperformance, both

20 on the abdominal as well as on the back muscle endurance test. A high BMI was even a predictor of

21 underperformance on these two endurance tests. In the literature, BMI is often associated with lower

22 physical performance but also with a higher occurrence of psychosocial problems [Vaidya, 2006;

23 Fabricatore & Wadden, 2004].

24 The method used in this study to determine the group of underperformers and performers could be

25 questioned, because controversy exists concerning the use of MF_{slope} to determine the time to

26 exhaustion [Bouillard et al, 2012]. Because parameters derived from the EMG power spectrum are

27 less dependent on the force level of the muscle compared to amplitude parameters and appear to be

1   more sensitive to the myoelectric manifestations of muscle fatigue [Ng et al, 1996; Potvin & Bent,

2   1997], the use of spectral EMG variables as fatigue index was preferred over the EMG amplitude

3   parameters [Roy & Oddsson, 1998]. MF has been suggested to be the most suitable parameters for

4   describing localized muscle fatigue [Kankaanpää et al, 1998; Larivière et al, 2002] and may provide an

5   objective measure of muscle fatigue [Arnall et al, 2002; Mannion et al, 1998; Ng et al, 1996; Nicolaisen

6   & Jorgensen, 1985; Roy et al, 1989]. In contrast, Bouillard et al [2012] demonstrated that other

7   physiological (e.g. motor unit synchronization) and non-physiological (e.g., change in fiber pennation

8   angle, change in the muscular temperature) factors may affect the sEMG signal and thus its changes

9   over time. Other parameters have also been proposed, such as the Dimitrov spectral index, which was

10   shown to be higher correlated with endurance time than the initial slope of the MF in a small healthy

11   population performing isotonic biceps brachii contractions [Lee et al, 2011]. In addition, the MF was

12   demonstrated to be not a suitable indicator for dynamic contractions [Van Dieën et al, 1996] and

13   contractions at approximately 9-10% of maximal voluntary isometric contraction (MVIC) [Gonzalez-Izal

14   et al, 2010]. However, since most of the studies analyzing back muscle fatigue have used MF [Allison

15   & Henry, 2001; Biedermann et al, 1990; Champagne et al, 2008; Dedering et al, 2000; Elving et al,

16   1999; Kankaanpää et al, 1998; Larivière et al, 2002; Mannion et al, 2011; Müller et al, 2010; Ng et al,

17   2002; Peach & McGill, 1998; Süüden et al, 2008], and the endurance tests were not dynamically

18   performed and achieved higher levels than 9 to 10% of MVIC, the method applied in the present study

19   was choosen. However, the accuracy of the method using MF_{slope} to estimate the endurance time is

20   not known and thus some participants may not have been well classified. In addition, the low R^2

21   values could induce some doubt about the usefulness of the linear regression models. But R² is not a

22   way to decide if a model is good or bad and that prudence is warranted in interpreting R² values

23   (Achen, 1977; Kennedy, 2008; Goldberger, 1991; King, 1986).

24

25   Finally, the aim of this study was not to make a model to predict underperformance on endurance test,

26   but to demonstrate, in addition to previous research, that endurance time on the B-S test and the AE

27   test is not a clear measure of intrinsic muscle fatigue. Psychosocial components and reporting on

28   physical health are interacting with performance on these tests and should be taken into account while

making conclusions based on these tests. In addition, differences found between the AE test and B-S test in this study indicate that these interactions could be test-specific. So these results cannot be generalized to all performance measures. There is a clear need for the use of sEMG in measuring intrinsic muscle fatigue in research and/or clinical settings. Using sEMG in the clinical practice is not feasible, but clinical practitioners, who want to measure endurance, should be aware that psychosocial components could influence performance.

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1   **Caption to illustrations**

2   Figure 1 The abdominal endurance test

3   Figure 2 A modified version of the Biering-Sorenson test

4   Figure 3 Plot of the real endurance time (ms) versus the normalized slope of the multifidus, for male

5   and female patients, during a modified version of the Biering-Sorensen Test. The predicted endurance

6   time is given by the regression equation for each gender separately. The regression line for the male

7   was: Y= 122244 + (6638904*x). For female subjects the regression line was Y= (122244-18289) + (

8   6638904*x).

9   Figure 4 Plot of the real endurance time (ms) versus the normalized slope of the internal obliques, for

10   male and female patients, during an abdominal endurance test. The predicted endurance time is given

11   by the regression equation(Y= 135858,264 + (11104256,44*x), which was found identical between the

12   two genders.

Fig 1

Fig 2