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The Comprehensive Muscular Activity Profile (CMAP): Its Clinical Utility in Objectively Differentiating Between Low Back Pain Patients and Normals[1]

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Earlier findings demonstrated that the comprehensive muscular activity profile (CMAP) system was a powerful clinical method for evaluating lumbar range of motion (ROM) and lifting capacity (LC) while also documenting participant effort. A subsequent study also reported the CMAP's clinical utility for patients with musculoskeletal pain claims. Building upon these studies, the present investigation evaluated the CMAP's ability to reliably differentiate between healthy individuals versus those with low back pain (LBP). Twenty LBP patients and 20 demographically matched healthy subjects were administered the CMAP protocol (measuring ROM and LC). For ROM, there were no significant differences between the groups for overall performance and for degree of effort. However, for the LC, there were significant differences between groups: the LBP patients displayed lower performance relative to normals. Results demonstrate the clinical utility of the CMAP for the objective quantification of functional differences between the two groups.

Introduction

Earlier findings from a randomized controlled trial reported in this *Journal* demonstrated that a new comprehensive muscular activity profile (CMAP) system was a powerful clinical method for evaluating lumbar range of motion

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(ROM) and lifting capacity *while also documenting participant effort* during these performance tasks (Gatchel, Ricard, Choski, Mayank, & Howard, 2009). As noted in that study, a long-standing problem encountered by clinicians who attempt to objectively assess musculoskeletal disorders such as low back pain (LBP), where there is often primarily soft tissue involvement, is the fact that psychosocial factors (such as fear avoidance of movement, secondary gain, etc.) may influence the experiencing/reporting of pain during the assessment process. This can create a major dilemma whenever one evaluates disorders such as LBP, especially in workers' compensation or personal injury populations, because the degree of physical impairment must be considered for employment/injury compensation issues. Indeed, such compensation issues are quite costly to society, with about 80% of all workers' compensation health care costs are attributed to approximately 10%–15% of the total cases who ultimately develop persistent chronic pain problems initially associated with soft tissue injuries (e.g., Nemeth, Novak, & Gatchel, 2005).

Unfortunately, although physical impairment (i.e., the alteration of an individual's usual health status, because of anatomic or pathologic abnormalities) needs to be evaluated, there is currently still no universal agreement about what measures should be used in impairment evaluation because of concerns about the objectivity/validity of such measures (Gatchel, Ricard, Choski, et al., 2009). In the past, one such potentially objective measure that has received a great deal of attention for musculoskeletal disorders has been surface electromyographic (sEMG) recordings during purposeful muscular activity and resting states. However, there has been some differing opinions concerning its validity in differentiating between LBP patients and normals (e.g., Haig, Gelblum, Rechtine, & Gitter, 1996, Pullman, Goodin, Marquinez, & Rubin, 2000). Geisser et al. (2005) subsequently concluded that the results were indeed quite mixed and called for more clinical research to determine what measure(s) are "reliable, valid and discriminate with a high degree of accuracy between healthy persons and those with LBP" (p. 711). Their call stimulated the earlier published study by Gatchel and colleagues (Gatchel, Ricard, Choski, et al., 2009), which demonstrated the utility and validity of the CMAP, as well as a subsequent study by Gatchel and Theodore (2009) that reported some preliminary findings revealing the CMAP's clinical utility for patients with musculoskeletal pain claims. Building upon these two studies, the present investigation was designed to evaluate the ability of the CMAP to reliably differentiate between healthy individuals and those with LBP. Overall, this series of studies was designed to systematically assess the clinical utility of the CMAP, which is a safe, non-invasive, and potentially objective measure of muscle functioning/impairment in LBP. It is also significantly different and more advanced than the earlier approaches used for the measurement of sEMG.

Methods

Subjects

There were two groups of subjects recruited for this study. The first group consisted of 20 acute LBP patients (tested within 6 months of their initial injury) from a local occupational medicine clinic. These patients were paid $100 for participating in this study. Table 1 presents the basic demographics and injury characteristics of these LBP patients. As can be seen, the majority of these patients suffered from lumbar strains, and the average number of days between their injury and testing was 32. It should also be noted that, on subsequent statistical analyses, the type/cause of injury and time since injury did not affect results. The second group consisted of 20 healthy volunteers who were recruited through advertisements posted throughout a major university. These subjects were excluded if they had an injury that prohibited normal trunk ROM, or a muscle/joint injury that prohibited them from performing maximal isometric low back strength testing. These normal subjects were matched with the LBP patients on basic demographic variables. They were paid $25 for participating in the study (less than the patients because they did not have to drive to an off-campus testing center). It should also be noted that, because of equipment malfunctioning, there were not usable data for one LBP patient, and another patient had ROM performance and effort data but no data for the lifting tasks. Thus, there was a total of 39 participants with ROM data and 38 with lifting data.

Procedure

After completing the Institutional Research Board's informed consent, as well as a Health Status Questionnaire, subjects were tested at the occupational medicine clinic (patients) or at the University's Department of Kinesiology (normal subjects). The therapists (two graduate students [MJ, SG] in the department) administered the identical CMAP protocol at both sites.

CMAP Protocol

All subjects were administered three trials of each of the following:

- Rest sitting
- Rest standing
- Trunk flexion/extension
- Rest standing
- Trunk rotation, right and left

Table 1

Demographics and Injury Characteristics of LBP Patients

Age	*M* (43.8)	*SD* (8.6)
Gender	19 Males	1 Female
Time between injury and testing	*M*, days (32.0)	*SD*, (53.2)
Injury and cause of injury	P1	Lumbar strain; lifting
	P2	Lumbar strain; lifting
	P3	Lumbar strain; lifting
	P4	Lumbar-social strain; lifting
	P5	Chronic lower lumbar; twisting during lifting
	P6	Chronic lumbar pain; pulling
	P7	Thoracic; lifting
	P8	Lumbar strain; slipping
	P9	Lumbar strain; lifting
	P10	Lumbar strain; lifting
	P11	Lumbar strain; lifting
	P12	Lumbar strain; fork lift accident
	P13	Lumbar strain; bending injury
	P14	Lumbar strain; lifting
	P15	Lumbar-social strain; overuse bending
	P16	Lumbar-social strain; twisting during lifting
	P17	Lumbar strain; lifting
	P18	Lumbar strain; lifting
	P19	Chronic lumbar pain; pulling
	P20	Lumbar strain; bending injury

- Rest standing
- Lateral trunk bending, right and left
- Rest standing
- Isometric low back strength testing, underhand grip
- Rest standing
- Isometric low back strength testing, overhand grip
- Rest standing
- Rest sitting

All data were continuously uploaded to the Medical Technologies computerized system where muscle activity scoring/analyses were blindly conducted. All final CMAP data were then transferred to a data spreadsheet for subsequent statistical analyses by an individual (AD) who was "blind" as to the basic experimental hypotheses. *The CMAP Technology* has an FDA 510-K Class II approval, as well as approval from Underwriters Laboratory. It is a stand-alone dynamic muscle function monitoring system, with a number of EMG sensors connected to various parts of the subject's body for data collection. Again, as noted earlier, this technology is significantly different and more advanced than earlier methods in the measurement of sEMG.

Prior to attaching EMG electrodes, the electrode placement sites were shaved, abraded, and cleaned with an isopropyl alcohol pad to reduce skin impedance. Surface electrodes were then placed over the belly of the following muscles for the right and left side of the body, with the electrodes aligned in the direction of the muscle fibers: par spinal, quadrates, labarum, gluteus maximums, rectus abdominal, abdominal oblique, and biceps femoras. The data were then directly fed into a system of acquiring, conditioning, and transforming sensor data. Analyzed signals included EMG readings, motion detection, and muscle strength measurements. The system acquires continuous analog signals and then digitizes these by sampling at a rate of 15 kHz. These data are then transferred to a notebook PC for processing using proprietary software. The CMAP identifies valid effort by assessing the morphology and quantifying the EMG signal generated from a muscle or muscle group during the performance of a test. A "compliant" morphology is one in which the characteristic crescendo/decrescendo wave form appears when a muscle approaches its endpoint of range, or contracts against isometric resistance. It should also be noted that the system has dedicated circuitry to filter/shield out background noise (from the power supply, cabling, testing equipment, etc.). The EMG signals are differentially amplified with a gain of 2,000 in a bandwidth of 1–2,500 Hz. The amplifier has an input noise approaching 12 μV RMS and an effective common mode rejection ratio of about 80 dB. Two notch filters eliminate power line pickup at 60 and 120 Hz. The circuit also detects disconnected leads.

Data Analysis

After the processing of the sEMG data by CMAP's proprietary software (with participant group assignment being kept blind), the data were then transferred to an independent data spreadsheet from which the statistical analyses were conducted. Measures included the achievement of minimum AMA levels (American Medical Association, 2007) for ROM, lifting performance (with both underhand and overhand grips), and degree of effort (minimal or submaximal). It should be noted that the CMAP decision algorithm used in determining effort was based on a prior data set and not on the data collected in the present study. A series of 2 × 2 chi-square analyses were conducted for performance on each of the three measures, as well as valid effort on each measure (with the columns representing group assignment and rows representing either achieving minimum AMA levels for a particular measure, or the participant's effort during performance on that measure). Finally, the relationships between performance and effort on each of the three tasks were examined in order to better understand the clinical utility of the CMAP for differentiating LBP patients from healthy controls.

Results

ROM

Table 2 presents the chi-square analyses of the CMAP ROM results. As can be seen, there was neither a significant group effect for performance that met minimum AMA guidelines, nor for maximal effort on this test.

Table 2

Chi-Square Analyses of the Range of Motion Results

		Group		
Range of motion		LBP *n*	Healthy Controls *n*	Total *n*
Performance	Minimal	9	6	15
	Submaximal	10	14	24
	Total	19	20	39
Effort	Minimal	10	11	21
	Submaximal	9	9	18
	Total	19	20	39

Table 3

Chi-Square Analyses of the Underhand and Overhand Grip Lifting Results

		Group		
		LBP *n*	Healthy Controls *n*	Total *n*
Underhand grip lifting				
Performance	Minimal	10	4	14
	Submaximal	8	16	24
	Total	18	20	38
Effort	Minimal	13	10	23
	Submaximal	5	10	15
	Total	18	20	38
Overhand grip lifting				
Performance	Minimal	11	5	16
	Submaximal	7	15	22
	Total	18	20	38
Effort	Minimal	13	9	22
	Submaximal	5	11	16
	Total	18	20	38
		11	5	16

Lifting-Underhand Grip

For this lifting measure (Table 3), there was a significant performance effect difference between the two groups: X^2 (1, $n = 38$) = 5.15, $p < .05$; odds ratio (OR) = 5.00, 95% confidence interval (95% CI) (1.19–21.04). This indicated that the healthy participants had greater performance on this test. There were, though, no effort differences between the two groups.

Lifting-Overhand Grip

Similar to the other lifting task, there was again significant differences between the two groups on this lifting task (Table 3). The healthy participants had greater performance: X^2 (1, $n = 38$) = 5.07, $p < .05$; OR = 4.71, 95% CI (1.18–18.86). They also demonstrated marginally better effort on this test: X^2 (1, $n = 38$) = 2.88, $p = .09$; OR = 3.18, 95% CI (.82–12.34).

Relationships Between Performance and Effort

As expected, each of the three performance measures was positively associated with its respective effort measure. Table 4 presents the respective breakdowns for these associations. For ROM, there was a large positive correlation for the entire sample, $r(39) = .63$, $p < .001$. This correlation was larger in the LBP group, $r(19) = .90$, $p < .001$, than in the healthy control group, $r(20) = .37$, $p = .11$, $z = 3.10$, $p < .01$. These relationships were similar for the lifting tasks, but the magnitude of the correlation coefficients were not significantly different. The correlation between performance and effort on the underhand lifting task was large and positive in the overall sample, $r(38) = .62$, $p < .001$, as well as in the LBP group, $r(18) = .69$, $p < .001$, and the healthy control group, $r(20) = .50$, $p < .05$, $z = 0.86$, $p = .39$. Similarly, the correlation between performance and effort on the overhand lifting task was large and positive in the overall sample, $r(38) = .73$, $p < .001$, the LBP group, $r(18) = .78$, $p < .001$, and the healthy control group, $r(20) = .64$, $p < .01$, $z = 0.80$, $p = .42$.

Discussion

The findings of the present study demonstrate the clinical utility of the CMAP for the objective quantification of functional differences (lifting performance) between LBP patients and healthy normal subjects. The results demonstrated significant lifting performance differences between the two groups but no ROM differences. Moreover, there were no performance effort differences between the two groups on any of the tests. This suggests that subjects in both groups were motivated to perform, perhaps because of the monetary reward provided to them. In future studies, it would be interesting to observe if effort would be negatively affected if such monetary incentive was not provided. Indeed, in the earlier study by Gatchel et al. (Gatchel, Ricard, Choski, et al., 2009), it was found that effort could be affected by "secondary gain-type" instructions.

Together with the earlier reviewed investigations by Gatchel and colleagues (Gatchel, Ricard, Choski, et al., 2009 and Gatchel and Theodore 2009), these results further attest to the clinical utility of the CMAP, which is a safe, non-invasive, and objective measure of muscle functioning/impairment, as well as subject effort during the measurement process. Such findings have significant clinical implications for physical impairment evaluations. Indeed, as previously highlighted by Gatchel et al. (Gatchel, Ricard, Choski, et al., 2009), whenever one evaluates painful musculoskeletal disorders (such as LBP), especially in

Table 4

Cross-Tabulation of Performance and Effort Variables for Each Measure by Group

		Effort		
Performance		Minimal *n*	Submaximal *n*	Total *n*
LBP				
Range of motion performance	Minimal	9	0	9
	Submaximal	1	9	10
	Total	10	9	19
Healthy controls				
Range of motion performance	Minimal	5	1	6
	Submaximal	6	8	14
	Total	11	9	20
LBP				
Underhand grip lifting performance	Minimal	10	0	10
	Submaximal	3	5	8
	Total	13	5	18
Healthy controls				
Underhand grip lifting performance	Minimal	4	0	4
	Submaximal	6	10	16
	Total	10	10	20
LBP				
Overhand grip lifting performance	Minimal	11	0	11
	Submaximal	2	5	7
	Total	13	5	18
Healthy controls				
Overhand grip lifting performance	Minimal	5	0	5
	Submaximal	4	11	15
	Total	9	11	20

workers' compensation or personal injury populations, it is mandatory that the degree of physical impairment be considered for employment/injury compensation issues.

In terms of impairment, Gatchel, Ricard, Brede, and Worzer (2009) reviewed its definition as the alteration of an individual's usual health status because of anatomic or pathophysiological abnormalities. For LBP, it is often evaluated by measuring physical functioning, such as ROM, lifting capacity, aerobic capacity, as well as other measures of human performance (e.g. Flores, Gatchel, & Polatin, 1997). Unfortunately, however, there has still not been a "gold standard" or universal agreement about what measure(s) should be used in impairment assessment for primarily soft tissue injuries such as LBP. This has presented a significant problem for clinicians who attempt to objectively document any impairment, because psychosocial factors frequently affect the experience/reporting of such soft-tissue injury pain (Mayer, Gatchel, & Polatin, 2000). For example, secondary gain issues and neuromuscular inhibition because of fear avoidance of movement have been shown to significantly impact physical performance (e.g., Leeman, Polatin, Gatchel, & Kishino, 2000; Rainville, Sobel, Hartigan, & Wright, 1997). In light of such factors, there have been attempts to develop better quantification techniques of physical functioning, coupled with appropriate validity indices, in order to evaluate both physical impairment, as well as a therapeutic endpoint following treatment intervention.

As we reviewed earlier in this present article, one such potentially objective measure that had received a great deal of attention for musculoskeletal disorders in the past has been sEMG recordings during purposeful muscular activity and resting states. However, the utility of such recordings have been called into question because of validity and reliability issues (e.g., Geisser et al., 2005). This subsequently stimulated the development of the CMAP system, which has now been shown to be valid for evaluating lumbar ROM and lifting capacity while also documenting subject effort during these performance tasks (Gatchel, Ricard, Brede, et al., 2009; Gatchel, Ricard, Choski, et al., 2009; Gatchel & Theodore, 2009).

It should also be noted that one initially unexpected result of the present study was the fact that lumbar ROM was not found to significantly differentiate between the LBP patients and their healthy counterparts. Moreover, the correlational relationships between performance and effort were different when comparing LBP and healthy participants. This leads us to conclude that ROM may not be as sensitive a measure as traditionally thought in evaluating physical impairment in LBP patients. Such a conclusion is reinforced by the fact that, unlike earlier versions of the American Medical Association's *Guides to the Evaluation of Permanent Impairment*, ROM is no longer included in the most recent 6th edition (American Medical Association, 2007). Thus, there appears to have been some wavering support/universal agreement concerning this particular measure for use in impairment evaluation. The present results add further to such diminished support.

In conclusion, the present study demonstrates the clinical utility of the lifting performance component of the CMAP for significantly differentiating between LBP patients and healthy normal subjects. It should also be noted that the CMAP is not only clinically useful in physical impairment evaluations in occupational medicine settings but can also be a valuable evaluation tool for determining a therapeutic endpoint following treatment in other clinical settings, as well as for clinical research. Indeed, with the increased emphasis on the need for evidenced-based outcomes for objectively documenting clinical outcomes and therapeutic efficacy, the CMAP is an ideal measure of physical function and associated effort to use in such clinical and research endeavors.

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