Spinal pain and postural sway.

Is there a relationship?

By

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Doctor of Philosophy

of

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

[Signature]

Alexander Ralph Ruhe
ABSTRACT

Postural stability is an important component in maintaining upright stance and balance during normal daily movements and activities. Postural stability is also an important factor in the elderly where balance disability may increase the risk of falls and subsequent injury. In sport, problems with balance may lead to serious injuries. Thus, postural stability has important implications in rehabilitation and sports.

Many different methods exist today for assessing postural sway. Centre of pressure (COP) evaluation is a frequently used method of measuring this stability and gain insights into potential pathological mechanisms e.g. in association with pain. This is possible as the COP signal is proportional to ankle torque, a combination of descending motor commands as well as mechanical properties of the musculature around.

Over the last decades, postural sway has been most commonly evaluated by using spatial measures such as sway distance, velocity and area traversed based upon sequential locations of the COP in the plane of the force platform. However, despite its common usage, important clinical aspects of the COP measurements such as its potential suitability for clinical monitoring purposes in pain patients remained unaddressed. Several literature reviews were conducted that identified relevant gaps in current knowledge to focus our research.

This led to the following primary research questions:

  a) Can a best evidence experimental setup be identified that is suitable for spinal pain sufferers?
  a) Is there a relationship between pain intensity and the COP excursions?
  b) Are there alterations in postural sway associated with diminishing pain?
Based on a systematic review of the literature the following experimental protocol was developed: Three measurements of 90sec each were conducted in bipedal narrow stance with closed eyes at a sampling frequency of 100Hz. We selected the COP parameters 90% circle diameter as a descriptor of sway area and mean sway velocity as it has shown its discriminative value for various pain conditions.

The prospective part of this thesis was preceded by pilot studies that confirmed the excellent reliability of the selected experimental setup for mean sway velocity in antero-posterior (AP) and the medio-lateral (ML) direction (ICC\textsubscript{2,k} 0.85-0.89, 95\% CI 0.63-0.97, SEM 0.66-0.78) and 90\% circle diameter (ICC\textsubscript{2,k} 0.80, 95\% CI 0.54-0.94, SEM 0.89). Later on, very similar values were observed for sway data obtained from the symptomatic groups.

The experimental setup was found to be safe and a sub-sample of predominantly low back pain patients (n=20) reported no difficulties complying with the postural tasks involved. Furthermore, no effects of learning or fatigue could be demonstrated in 10 healthy individuals either during inter-session (10 consecutive measurements) or intra-session (three times 3 measurements at 2-3 day intervals). No adverse incidents associated with the measurements occurred in approximately 1500 measurements.

By enrolling age matched healthy individuals as a control group (n=77), reference values for the included COP parameters were established to which all subsequent data obtained from symptomatic individuals could be compared.

A total of 210 patients were enrolled subdivided into three groups for non-specific neck, mid back and low back pain. A physical examination was conducted for all pain sufferers, who were asked to rate their pain intensity on a NRS-11 scale. The associated disability was assessed by means of the Disability Rating Index. Depending on the reported severity of their
complaint, the symptomatic individuals were subdivided into seven pain intensity groups (NRS 2-8) for each of the painful regions: low back (n=77, n=11/group), mid back (n=63, n=9/group) and neck (n=70, n=10/group).

The symptomatic participants exhibited greater postural sway than healthy controls. As a general trend, a statistically significant increase was reached beginning at about NRS score 4 for all three pain regions. Depending on the COP parameter and painful region, significant differences between individual NRS levels were reached about every 2-3 NRS levels.

Significant differences in COP excursions between mid back, low back and neck pain sufferers could be identified. However, in the light of the expected inter-subject variability in pain perception as well as the low number of participants per NRS group this conclusion warrants caution.

A major finding from a univariate regression analysis was a linear relationship between pain intensity and the COP parameters (p<0.001) for all painful regions, while a multivariate regression analysis showed that other variables such as age, gender, height, weight and BMI did not have a statistically significant effect on postural sway.

This close relationship was maintained even with diminishing pain levels after a course of manual therapy treatments conducted in a group of low back (n=38) and neck pain patients (n=36). In this instance three measurements and interventions were performed at 3-4 day intervals. With few exceptions, the follow-up COP measures in connection with specific pain intensities did not show a significant difference in postural sway compared to reference values for identical NRS levels at baseline.
In addition, a similar linear relationship between pain intensity, the COP sway parameters and the patient's disability ratings was identified for all painful regions.

At the same time, a clear trend towards predominant sway in the medio-lateral direction was observed with increasing pain intensities, until 70% of sway occurred in ML direction at NRS score 8. In comparison, healthy controls showed a nearly equal sway distribution between AP (52%) and ML (48%) direction.

In the absence of learning effects, the reduced COP excursions with decreasing NRS scores in subacute and chronic pain sufferers further suggests that pain interference rather than long-term neuro-physiological adaptations (such as central sensitization) are the primary causative factor for increased sway.

Our findings may have clinical implications for COP measures in patients with significant pain. These include routine sway analyses as an objective outcome measure during the rehabilitation and treatment process. It also stresses the importance of an initial focus on pain regulation rather than proprioceptive training.
ACKNOWLEDGEMENTS

My path towards undertaking and completing a higher qualification by research has been reinforced and received direction and support from a wide range of individuals along the way.

Since undertaking the studies towards this PhD, my supervisors were a tremendous source of knowledge, energy and support. Dr Bruce Walker from the School of Chiropractic and Sports Science at Murdoch University and Dr René Fejer from the Spine Centre of Southern Denmark and University of Southern Denmark provided me with high levels of autonomy and yet they were always available as sources of information. Especially with Dr Fejer the "quick chat" we would arrange were sure to turn into an in-depth discussion lasting for hours into the night. In these years both have provided a strong research methods background, coupled with a keen analytical approach to the research questions investigated as well as an extremely valuable critique of all my written material. At the same time, they also reminded and encouraged me not to disregard my private life, especially during the rather frantic later stages towards completion. The combination of these two supervisors, both with different styles and approaches to the rigors of completing a PhD, has provided an excellent basis to further develop from this point and I am deeply grateful for this. While they contributed greatly, I bear full responsibility for the content of this thesis and any mistakes associated with it.

The Praxis für Chiropraktik Wolfsburg provided a highly supportive environment which allowed the combination of clinical work and research activity. The thesis would not have been possible without the help of my colleagues Alexander Steinbrenner DC and Tino Bos DC who provided a room for the measurements, helped with the literature search and conducted the physical examinations, patient documentations and treatments during the prospective part of this thesis.
In addition, I am very grateful for the invaluable and essential support by the clinic staff during the process of patient recruitment. Each of them agreed to spend additional time in clinic copying and distributing information material and in doing so, they freed up valuable time for me to pursue other tasks associated with the conduct of the experiments.

External assistance also contributed to this project and I am indebted to the reviewers of the publications arising from this project. Based on long experience in the field of postural sway analysis, their valuable input added depth to the discussions and further strengthened the final manuscript of this thesis.

Another important source of support was my family. While not being directly involved in the conduct of this thesis, they contributed substantially by simply listening to my thoughts when I constantly developed and dismissed new ideas, offering encouragement and giving me the feeling that they were with me along the way. My father and sister also shared anecdotes from their own experience completing research doctorates that were both inspiring and reassuring.

Finally, I thank my wife Sina for encouraging, supporting and enduring my endeavors over these past years. I cannot count the times I apologized for my absence of thought and moods when I returned once again late and exhausted. At the same time, there has been nothing better than coming home after a long day of clinic and research when things have not always gone well, knowing that a welcoming reception will be given and that the day’s problems will soon be put into context and perspective. Sina, you have provided me with tremendous support and inspiration and I believe it is fair to say that I would not have reached this point without you.
PUBLICATIONS ARISING FROM THIS THESIS

Papers


Posters and Abstracts


Ruhe A, Fejer R, Walker BF. Inter- and intrasession effects of learning and fatigue on center of pressure measures in healthy individuals. European Chiropractors' Union, ECU Convention, 02-04 June 2011, Zurich, Switzerland.

Ruhe A, Fejer R, Walker BF. Associations between non-specific manual interventions and the magnitude of COP excursions in NSLBP patients. European Chiropractors' Union, ECU Convention, 02-04 June 2011, Zurich, Switzerland.


Ruhe A, Fejer R, Walker BF. Inter- and intrasession effects of learning and fatigue on center of pressure measures in healthy individuals. Chiropractors and Osteopaths College of Australasia, 10th Biennial Conference, 8-9 October 2011, Melbourne, Australia.


**Podium presentations**


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<tr>
<td>A/D</td>
<td>analogue-to-digital</td>
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<tr>
<td>AMTI</td>
<td>Advanced Mechanical Technology Incorporated</td>
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<tr>
<td>AP</td>
<td>anterior-posterior</td>
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<td>ART</td>
<td>active release technique</td>
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<tr>
<td>BBS</td>
<td>Berg balance scale</td>
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<tr>
<td>BOS</td>
<td>base of support</td>
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<tr>
<td>C</td>
<td>compliant surface (on force platform)</td>
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<tr>
<td>CI</td>
<td>95% confidence interval(s)</td>
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<td>CLBP</td>
<td>chronic low back pain</td>
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<td>COP</td>
<td>center of pressure</td>
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<td>COM</td>
<td>center of mass</td>
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<tr>
<td>COG</td>
<td>center of gravity</td>
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<tr>
<td>CNS</td>
<td>central nervous system</td>
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<tr>
<td>CV</td>
<td>coefficient of variation</td>
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<td>DCG</td>
<td>German Chiropractors' Association</td>
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<tr>
<td>DFA</td>
<td>detrended fluctuation analysis</td>
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<td>d or dist</td>
<td>distance</td>
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<tr>
<td>DRI</td>
<td>disability rating index</td>
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<tr>
<td>DSN</td>
<td>diabetic sensory neuropathy</td>
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<td>EC</td>
<td>eyes closed</td>
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<td>EMG</td>
<td>electromyography</td>
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<tr>
<td>EO</td>
<td>eyes open</td>
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<tr>
<td>F</td>
<td>firm surface (on force platform)</td>
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<td>FABQ</td>
<td>fear avoidance belief questionnaire</td>
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FD  fractal dimension

$g$  gravity

GC  generalizability coefficient

GF  gauge factor

GRF  ground reaction force

H  Hurst-component

HVLA  high velocity, low amplitude (manipulative thrust)

ICC  intra-class correlation coefficient

L  length

LB  large base (forceplate)

LBP  low back pain

LEI  lower limb injury

$M_{x,y,z}$  moments acting on the platform

ML  medio-lateral

MMDC  minimal metrical detectable change

mod  moderate

mPos  mean position

ms  milliseconds

mValue  mean value

mVel  mean (sway) velocity in mm/s

n  number

NB  narrow base

NDI  neck disability index

Nm/rad  unit (kinetics) for torque

NP  neck pain

NRS  numeric rating scale (NRS-11)
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<td>ns</td>
<td>not significant</td>
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<td>non-specific low back pain</td>
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<td>NSMBP</td>
<td>non-specific mid back pain</td>
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<td>NSNP</td>
<td>non-specific neck pain</td>
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<tr>
<td>PASW</td>
<td>predictive analytics software</td>
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<tr>
<td>PCC</td>
<td>Pearson's correlation coefficient</td>
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<td>PIR</td>
<td>post-isometric relaxation</td>
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<tr>
<td>RC</td>
<td>reliability coefficient</td>
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<td>RMS</td>
<td>root mean square</td>
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<td>ROM</td>
<td>range of motion</td>
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<td>RTA</td>
<td>road traffic accident</td>
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<td>stabilogram diffusion analysis</td>
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<td>standard error of measurement</td>
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<td>SI</td>
<td>stability index (COP parameter)</td>
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<td>SL</td>
<td>single leg</td>
</tr>
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<td>SLR</td>
<td>straight leg raise (orthopedic test)</td>
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