



The CHIROPRACTIC CLINICIAN

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DEPARTMENT OF CHIROPRACTIC
UNIVERSITY OF JOHANNESBURG



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The Future
Reimagined



LETTER FROM THE EDITOR

It is with great pleasure that the Department of Chiropractic, University of Johannesburg, launches the first edition of “The Chiropractic Clinician”. This has been a potential project for some time and we have now managed to create a South African journal, for the Chiropractic profession.

The aim of this journal at this stage, is more to promote research conducted within the two South African institutions, and allow those practitioners that are interested in writing articles, or have seen cases in practice that were perhaps different, a platform for submission for the benefit of the profession.

The first edition has varied articles, from history to dermatology to pediatrics and more specific research as conducted within the institutions, on the effects of the chiropractic manipulation on different conditions.

I would hope that the content stimulates discussion, and fosters an increased appreciation for the need for research within the South African context.

Enjoy the reading, and if you have any comments please feel free to contact me.

Regards,

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GUIDELINES FOR SUBMISSION

Title page

All aspects of the title page must be completed and signed. Any incomplete documents will automatically be sent back to corresponding authors

Abstract

This must not exceed 250 words. It should be structured with subheadings of objectives, methods, results, conclusions. No references should be included in the abstract

This must be submitted in word format.

Blinded manuscript

Manuscripts must be prepared in accordance with the Declaration of Vancouver “Uniform Requirements for Manuscripts Submitted to Biomedical Journals” (available from www.icmje.org).

The journal will adopt a blinded review process. Manuscripts should therefore included the title, but details pertaining to the authors must be removed.

The following headings should be used: Introduction, Methods, Results, Discussion, and Conclusion

Ethical considerations including approval by a registered ethics committee, and numbers, must be included if participants were included in the study.

Figures must be submitted in JPEG/TIFF format.

Referencing must follow Harvard format. Guidelines for referencing are available on <https://www.uj.ac.za/library/research-support/Pages/research-tools.aspx>

This must be submitted in word format.

All submissions will be verified via Turinitin to ensure no plagiarism exists.

IMPORTANT INFORMATION

All submissions must be made to chrisy@uj.ac.za.

Authors wishing submit should be aware that the journal has a policy of evidence based approached to chiropractic, and articles should reflect this.

The editor or staff of UJ reserve the right to reject any submission at their sole discretion should they determine submissions are not compliant with requirements, format, referencing, ethics, content, standard etc.

A Brief History of Chiropractic in South Africa: 1926-1989

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ABSTRACT

Objective: The objective of this paper was to record some of the more significant events that occurred in the evolution of the chiropractic profession in South Africa, from the arrival of the first chiropractor in the country to the beginning of the first government-subsidised educational programme.

Method: The material included was derived from official and unofficial documents, email communications and personal recollections.

Results: The production of what is believed to be the most comprehensive such publication on this topic.

Conclusion: Hopefully, the ambit of this paper will not only generate a greater appreciation of what has been achieved by the chiropractic profession in South Africa, but also stimulate the production of further writings on the topic.

INTRODUCTION

The author is unaware of any publication on the overall history of chiropractic in South Africa in a peer-reviewed journal. This paper is designed to help fill that gap.

In the beginning

In an email, Peters (R Peters 2015, personal communication, 1 June) stated that Henry Otterholt, an American graduate of the Palmer School of Chiropractic, arrived in Cape Town from New Zealand in April of 1926. No evidence of an earlier chiropractor in the country has been found. After a month of looking around, Otterholt established a practice in Adderley Street, Cape Town employing a lady attendant who could speak English, Afrikaans and Dutch. Peters added that within a month of opening his practice, Otterholt was apparently doing quite well, continuing for about a year before selling the practice to John Andrew Blackbourn. Blackbourn, a New Zealander, who had spent the previous year in the United Kingdom, during which time he was elected as the first Secretary/Treasurer of the British Chiropractic Association at its inaugural meeting in London on 31 May 1925, according to an email (R Peters 2015, personal communication, 25 May). After selling the practice, Otterholt returned to the USA. Blackbourn did not practice for long in Cape Town, traveling on to Australia in the same year.

It is not known when the first South African citizen to become a chiropractor arrived in the country, but the twins, Alan and Ivan Payne might have been amongst the earliest, qualifying in 1937 from the Lincoln Chiropractic College and returning to South Africa in 1938 (Brantingham and Snyder, 1999). Other early arrivals included Unity Lewis, Hilton Taylor and Owen "Jock" Roberts (Till, G.(a)).

Associations

It is claimed in an email (S Haldeman 2017, personal communication, 25 October) that Blackbourn established the South African Chiropractic Association (SACA) in 1926. However, if he was the only chiropractor in South Africa at that time, as would seem to be the case, one has to ask, how likely is it that a person would establish a professional association just for himself and then leave the country shortly thereafter? Furthermore, what might the legal or other requirements be for such an association to be considered "established", and were they complied with? No evidence has been found for the existence of that association during that time, other than for the claim that it did exist. This issue remains unclear.

Given that associations facilitate social interaction, camaraderie and the development of the best interests of the profession and its members, Peters (1993) records that the South African Health Practitioners Association (SAHPA) was formed in Johannesburg in 1940. Members of the association included chiropractors, osteopaths and naturopaths. Peters (1993) further records that in 1943, the South African Manipulative Practitioners Association (SAMPA) was formed in Durban. Its members were predominantly chiropractors, but members other professions that made use of joint manipulation were also represented.

In 1947, the Medical Auxiliaries Bill was introduced in Parliament which, according to Peters (1993) could have brought the practice of chiropractic and those of other professions under the control of medicine. Consequently, the SAHPA and SAMPA merged into one association in order to increase the likelihood of success in opposing the legislation. The merger proved to be successful in this regards. Furthermore, the merger constituted unity within

the chiropractic profession which would last until 1952. The name of SAMPA was retained for the new association as it had already been registered in terms of the Companies Act.

In 1950, Joshua Haldeman and his family, including his son Scott, emigrated from Canada to South Africa, according to an email (Haldeman S 2017, personal communication, 25 October). Joshua Haldeman settled in Pretoria where he established a large practice according to emails from (R Peters 2015, personal communication, 25 May) and (S Haldeman 2017, personal communication, 25 October). In either 1943, according to an email (R Peters 2015, personal communication, 25 May) or 1947 in another email (S Haldeman 2017, personal communication, 25 October) Blackburn returned to South Africa and established, once again, a practice in Cape Town. In 1952, in an email (R Peters 2015, personal communication, 25 May) stated that Blackburn moved to Pretoria where he joined the Haldeman practice and either on his own, according to an email (S Haldeman, 2017, personal communication, 25 October) or with Joshua Haldeman, according to an email (R Peters 2015, personal communication, 25 May), established (or re-established) the South African Chiropractic Association (SACA). SACA was an association for so-called “straight” chiropractic, which, strictly speaking, would equate to “hand only, spine only” in terms of treatment. This was in contrast to the more eclectic approach of SAMPA. However, two concurrent chiropractic associations obviously put an end to the unity in the profession that had lasted a mere five years.

Realising that perpetuity of the profession could only be assured through appropriate legislation, and suspecting that a house divided against itself shall not stand, 1957 saw the first overtures for amalgamation of SACA and SAMPA (SAMPAC Executive Council (1957). Unfortunately, they were not successful.

In 1958, a proposal was made to change the name of South African Manipulative Practitioners Association (SAMPA) to the Pan-African Chiropractic Association (PACA). This was agreed to in 1959, as reflected in the PACA AGM Minutes. Peters (1993) records that the reasons for this were twofold: firstly, there were now a predominance of chiropractors as members and therefore there was a desire to create a name more specifically for chiropractic; and secondly, there were grandiose ambitions of spreading chiropractic throughout the continent of Africa.

In the mid- to late-1960s, Peters (1993) records that PACA and SACA each approached the government separately with requests for legislation to recognise the chiropractic profession. The problem for the government, however, was with which of the two associations should it deal in order to develop such legislation? Feedback that these two associations continually got was to the effect, “If you people can’t decide what your own profession is all about, then don’t expect us to sort that out for you; get your house in order, speak with one voice and then we might listen to you”.

Fortunately, good sense eventually prevailed, and at a meeting of the councils of both SACA and PACA (PACA/SACA Minutes 1970), it was agreed to dissolve both associations and to form a single, new association representing the entire chiropractic profession, namely the Chiropractic Association of South Africa (CASA). The first General Meeting of the new association was held on 16 January 1971 (CASA Minutes, 1971), and since then, CASA has remained the only association representing the profession in South Africa, with the exception of a new association, the Association of Straight Chiropractors, which was formed shortly after the amalgamation, by a few ex-SACA members. However, according to Peters (1993) this association was disbanded in 1975.

Legislation and Commissions of Inquiry

According to the PACA Minutes of 13 March 1959, an opportunity arose to have the Confederation of Labour, probably the largest trade union in the country at that time, to back legislation recognising chiropractic. Peters (1993) reported that a Joint Legislative Committee was established, consisting of members of both SACA and PACA councils, which worked well in its negotiations with the Confederation of Labour and in developing a draft bill that would recognise the chiropractic profession, to be presented to parliament. PACA Minutes (1960) reflect that Mr BJ van der Walt, MP for Pretoria West, was identified as the most appropriate person to present the bill. Unfortunately, the bill did not appear on the order paper for 1961 due to a lack of time. However, as reported in PACA Executive Council (1961), both cabinet and caucus approved its inclusion for 1962. This way, the bill now had the backing of the government and was no longer just a private member’s bill.

The tabling of the bill, as referred to above, duly took place, but on 22 March 1962, during the second reading, the debate became so heated that the then Minister of Health, Albert Hertzog (non-medical), withdrew the bill and, as described by Peters, (1993) announced that he would establish a Commission of Inquiry into Chiropractic. The terms of reference of the Commission were to determine:

- (a) whether the work of chiropractors is a useful and necessary adjunct to the ordinary health services;
- (b) if there is any inherent danger to the public health by their treatment;
- (c) if chiropractic has definite advantages, and whether the recognition of chiropractic as a profession is justified and under what circumstances, if any, such recognition should be granted.

Peters (1993) describes aspects of how the Commission carried out its mandate as well as its findings. Compared to other inquiries into chiropractic, e.g. the Lacroix Commission in Canada, the Webb commission in Australia and the New Zealand inquiry into chiropractic, each of

which took 18 to 24 months to complete, the South African commission completed its work in about six months. PACA offered to bring leading academics out from the USA to testify, but the commission felt that such was unnecessary. It also offered to allow members of the commission to observe chiropractors at work in their practices, but likewise, it was considered unnecessary by the commission. Some years later, when CASA was drafting a rebuttal to the commission's report, a senior counsel that CASA had engaged for the task, said that he thought that the report was the worst example of a governmental commission that he had ever seen, and that the best that could be said about it was that "it was less than thorough". It was therefore not surprising that the commission's findings were very negative, it stating that:

- (a) chiropractic had no scientific basis;
- (b) there was no evidence of clinical effectiveness or safety;
- (c) any benefit that may be derived from chiropractic should be incorporated into the work of physiotherapists or orthopaedic surgeons; and
- (d) therefore, no legislative recognition should be afforded the profession.

According to Peters (1993), "When the Commission tabled its report to Dr Herzog in 1963, he informed PACA that 'to publish the report was not in the interests of the public nor of the chiropractic profession' (and) he was thus pigeonholing it, and did not intend tabling it in Parliament. His reasons for this were that it was filled with so many inaccuracies, pomposities, and had used so much medical 'hearsay' that it was blatantly biased. This in contrast to the disregard of its own demands of the chiropractic profession who were ordered to produce authenticated, notarised clinical case histories with, where possible, X-ray and laboratory back-up especially in cases where medical treatment had ostensibly been unsuccessful. When these arrived by the thousands, the Commission chose to disregard them in their entirety as being 'hearsay' or 'anecdotal' and were thus of no consequence."

In 1959, the government established a Commission of Inquiry into Ionizing Radiation – see PACA Members (1959). Given the extensive use made of x-rays by chiropractors in those days, the Joint Legislative Committee again sprang into action and, as described by Peters (1993), produced a memorandum of facts and arguments for the continued use of x-ray equipment by chiropractors. Although the profession did not escape criticism when the Commission produced its report in 1965, chiropractic installations rated well above average for the country, higher than dentists, some hospitals and some medical users. The outcome of this inquiry was to allow chiropractors to continue using x-ray equipment, with certain safety provisions required.

As mentioned above, the 1960's were without any significant legislative activity, the profession being repeatedly told to "get its house in order". Therefore, PACA and SACA on 31 October 1970 agreed to merge the two associations

as recorded in SACA/PACA Executive Councils (1970) and Peters (1993), and confirmed at the first general meeting of the newly-formed Chiropractic Association of South Africa (CASA), at which members of both previous associations were in attendance, as recorded in CASA members (1971).

The now unified profession approached the then Minister of Health, Carel de Wet, with great enthusiasm and optimism, seeking legislation that would, once and for all, properly recognise the profession. Little did the profession realise that the then Minister was not an enthusiastic supporter of chiropractic, he saying, yes, that he would draft a bill for the profession, but, as recorded by Peters (1993) that it would be based on the recommendations of the 1962 Commission of Inquiry into Chiropractic, and that he would be tabling that report in Parliament, a report that had been pigeon-holed by a previous Minister.

The above bill made provision for the "listing" of those persons already practising chiropractic, along with those persons studying in order to become chiropractors, and after that, NO ONE ELSE – see Chiropractors Bill (1971). In other words, unless the legislation was amended, the profession would eventually die out. Persons wishing to be "listed" as a practitioner or student would need to be recommended by CASA. The legislation made no provision for a statutory council nor for ethical control over the members of the profession, yet, as recorded by Peters (1993) the Minister told us that once we got the ethical and educational standards elevated, consideration could be given to amending the legislation. How this was to be achieved was less than clear, given that CASA was given no "teeth" by which to do this.

This draft legislation created a major dilemma for the profession, resulting in a serious rift amongst the members. One group of members argued that the bill was an insult to the profession, a slap in the face, and therefore should be rejected out of hand. The other group argued that, yes, it was an insult, but at least it was "a foot in the door", "the thin edge of the wedge", and that in due course CASA could argue for appropriate amendments, as recalled by the author, Till G(b). Furthermore, as Peters (1993, p. 18) reported, at least the bill recognised CASA as the profession's official body. Eventually, following a poll of the members of CASA, it was agreed to support the Bill, and so the Chiropractors Act became law in 1971.

Over the next six or so years there were only a few minor amendments to the Act, the most notable being the inclusion of an ethical code (Chiropractors Amendment Bill, 1976). Interestingly, the homoeopaths, osteopaths, naturopaths and herbalists had obtained their first legislation in 1974, which included a code of ethics from the outset, to be implemented by their professional association, as recalled by the author who served as the first Registrar in terms of that legislation (Till, G(b)).

However, as reported by Peters (1993), at a meeting in 1977 with Minister Schalk van der Merwe, he stated that he wasn't prepared to consider any further amendments to

the Chiropractor's Act until CASA supplied him with three documents. These were:

1. A Memorandum on the State of the Art of Chiropractic;
2. A Rebuttal to the findings of the 1962 Commission of Inquiry into Chiropractic; and
3. Answers to questions raised in parliament during the debates on the Chiropractors Bill in 1971.

Each of these on their own was to be a huge undertaking. However, through the combined efforts of the members of council and a seconded member, along with significant input from the late Dr Joseph Janse of the National College of Chiropractic, the three documents were completed in about 18 months. A count of the total number of pages produced was 316 foolscap pages – see Peters (1993).

Just as CASA was about to submit the three documents to the Department of Health, a new Minister, LAPA Munnik, was appointed (August 1979), our documents being submitted in March of 1980 – see Peters (1993). Such changes in office always create a measure of anxiety as one never knows what the attitude of the new incumbent will be towards the profession, it all requiring the re-establishment of trust through getting to know each other.

Shortly after our submission, a meeting with the new minister was arranged. Following the usual pleasantries, the Minister asked, "Just what is it that you people want?" Well, you could have knocked us over with a feather! Never before, the author subsequently learnt, had the profession been given such an opening opportunity. The delegation explained that the profession needed legislation similar to that of the medical profession so that proper control could be exercised over the ethical conduct of practitioners, that educational programmes based on scientific evidence could be established, and that research projects could be initiated. The Minister made copious notes, saying that he would first familiarise himself with the three documents that had been submitted and would get back to us within three months. The delegation left the meeting saying that they had never felt as positive following such a meeting, as recalled by the author, Till, G(b).

In the interim, CASA arranged a meeting on 6 March 1981 with the then Medical and Dental Council of South Africa (now the HPCSA), for the purpose of establishing a better relationship with the medical profession and to explore the possibility of them taking chiropractic under their legislative wing. This was reported to the members of CASA as per CASA members (1981a) However, such was not to be the case, they turning the request down.

Following this, a meeting was then arranged with the Health Group of the then ruling party at which a plea for a political solution to our needs was made, given that the Medical and Dental Council had turned us down. No doubt this message was conveyed to the Minister of Health. Till, G(b).

True to his word, Minister Munnik called a meeting within the promised three month period. However, the meeting also included council members of the South African Homoeopathic Association (SAHA) representing persons registered in terms of the Homeopathic Act of 1974. The Minister said that he had a plan to help us, but warned us that we might not like what he had in mind but that we should be patient and hear him out. He said he was going to ask the Medical & Dental Council to take our five professions (homoeopathy, osteopathy, naturopathy, herbalism and chiropractic) under its legislative wing. He stated that he was well aware of the less than harmonious history between our professions and medicine, and that should medicine accept his request, that he would expect us to require some very clear guarantees regarding the perpetuity and development of our professions. In pursuance of this request of his, he planned giving our two groups each a 90 minute opportunity to present our respective cases to the medical representatives, including the Medical Association of South Africa. Till, G(b).

In order to help us better prepare our presentation, Andries Kleynhans, then head of the chiropractic programme in Melbourne, Australia, a past lecturer at the National College of Chiropractic in the USA, and who before that practised in South Africa for about 10 years, was invited to come and help us prepare the chiropractic presentation as per the CASA members (1981b). He spent about 10 days working with us in this regard Till, G(b).

The appointed day arrived (10 August 1981) and our presentation included an overview of chiropractic education, a description of what typically takes place in a chiropractor's office, the conditions most frequently treated by chiropractors, an overview of current research activities and excerpts from videos demonstrating various physical examination procedures commonly used by chiropractors. We emphasised the healthy attitude we had towards medicine and the need for better control over our members in terms of ethical conduct along with the need for establishing sound educational and research programmes. Kleynhans spoke on the development, standards and sustainability of chiropractic education. We finished off by handing out the various memoranda developed by Kleynhans and others, and finally, each medical delegate was handed a copy of the first edition of Scott Haldeman's book, "Principles and Practice of Chiropractic". Time was then given for questions. These largely revolved around vitalism and our scope of practice and were readily responded to. Till, G(b).

Some weeks later, we were informed by the Department of Health that the Medical & Dental Council had turned down the Minister's request to take our five professions under their wing. From "friends at court" we learnt that the vote had been 17 to 16 against taking us in. However, we were also told that we should not think that such a vote was a measure of our popularity, as some of our most vociferous detractors voted in favour of taking us in. Till, G(b).

What was perhaps of significance was that at about

the same time, a delegation from the American Medical Association was (AMA) visiting South Africa, as the Medical Association of South Africa was trying to be re-admitted to the World Medical Association. When the AMA representatives heard the above story, they said that, had they had the same opportunity in America, they would have accepted the professions with open arms and then “smothered them with love”!. Till, G(b).

The Minister’s next move was to get the Human Sciences Research Council to conduct a survey in order to determine the extent of the public’s use of the five professions as well as their level of satisfaction, the outcome being very favourable for all five professions. Therefore, armed with all these facts, the Minister argued that, as there was an obvious demand for the services of these professions, and as the Medical and Dental Council had turned these professions down, that in the public interest, he had no other option other than to create separate legislation to control these professions, which he then proceeded to do. Consequently, on April 21, 1982, Act 63 of 1982, the Associated Health Service Professions Act, came into being. Till, G(b).

First Statutory Board (Council)

As recorded by Peters (1993), it was on the 9th of August 1982 that the first statutory Board held its inaugural meeting in Pretoria, opened by Minister of Health, Cornelius “Nak” van der Merwe. He emphasised that the members of the Board should always act in the best interests of the public. To reinforce this principle, he left the members with the Latin phrase that he had learnt from one of his professors whilst a medical student, namely, *Salus aegroti suprema lex* – the health of the sick one (patient) is the supreme (highest) law. Till, G(b).

It took about 18 months to have all the regulations in terms of the Act drafted and approved by the Minister. The government was obviously satisfied with what had been done and the way the different professions had worked together, as in 1984 it was leaked to us that amendments to the Act to address the outstanding two issues, namely re-opening the registers of the professions and making provision for education, would take place in 1985. Till, G(b).

Education

On hearing of these proposed amendments, the Board immediately started planning a trip to visit overseas educational, accrediting and manufacturing institutions relevant to the five professions. With the fact that chiropractic registers had been closed for 13 years, and with our numbers having dropped from 174 in 1971 to about 100, it was obvious that the profession in South Africa had lost touch in many ways with developments in terms of education, research and standard setting (accreditation). It therefore became critical that efforts be made in order to fill this hiatus. It became clear, therefore, that a variety of countries would need to be visited in order to gain the necessary information to fill these

gaps in preparation for our own education. Therefore, North America, the UK and certain European countries would need to be included in the itinerary. Consequently, a delegation of three members from the Board visited 8 chiropractic colleges in the USA, Canada and the UK, two accrediting agencies (CCE in the USA and Canada), 4 naturopathic colleges, 1 osteopathic school and 5 homoeopathic institutions including homoeopathic medical doctors. On their return, a comprehensive report was written with recommendations, which in turn was submitted to the Department of Health. Till, G(b). It would seem that the Department liked what they read, as the following year the two remaining issues in the Act were rectified.

The next task was to draft curricula for the proposed professional programmes. The Board felt that it was unlikely that the government would support and subsidise the establishment of five new educational programmes. Therefore, the Board reasoned that, as chiropractic and osteopathy had much in common in terms of managing musculoskeletal disorders, and as chiropractic and naturopathy had much in common in terms of encouraging patients to follow healthier lifestyles, it felt that an amalgamation of the best of those three professions would be reasonable. Similarly, the Board reasoned that there could be a rational argument for combining the best of homoeopathy, naturopathy and herbalism. The umbrella names for these amalgamations would be chiropractic and homoeopathy, they being the two largest of the five professions. Till, G(b).

True to its word, the Department amended the Act in 1985 in order to create educational opportunities for the professions as well as to re-open the registers.

It then became necessary for the Board to hold meetings with the Department of Education in planning the way forward. It was during this time in which the Board was informed that it was government policy that all new vocational programmes would have to be offered through technikons. Undeterred by this, the already drafted curricula for the two proposed programmes were forwarded to all institutions of higher learning in South Africa, asking them if they were interested in offering such programmes and if they had the facilities to do so. Eleven universities and eight technikons were approached in this regard with only one university (Western Cape), but 7 technikons expressing interest. A delegation of Board members and persons representing CASA and SAHA visited all eight institutions, assessing them in terms of location, facilities, attitude, academic staff and research activity. Till, G(b).

The upshot of this assessment was a unanimous vote in favour of Technikon Natal, with the second choice going to Technikon Witwatersrand. Agreements were signed with the Technikon Natal and towards the end of 1985 began the task of preparing the facilities. A new building was required, anatomy labs to be built, arrangements for obtaining cadavers made along with the legal requirements, and additional academic and administrative staff had to be planned for. Till, G(b).

The ensuing years saw an amazing amount of work done by the Technikon management, CASA and SAHA councils and the Board. The Technikon was unstinting in its support for the programmes. However, one of its requirements was that the professions needed to financially guarantee the first two years of the programmes. In this regard, the members of CASA raised well over a million rand. The then Rector of Technikon Natal said that, in all his years in higher education, he had never witnessed such support by a profession for its educational programme.²¹ Of course, it goes without saying that all of those people who were involved in all these developments, are now the “old timers” in the profession – that is, those who are still left. Till, G(b).

And so, in January of 1989, the first students were admitted into the first chiropractic programme in South Africa. This brought to a climax a history of many courageous, hardworking, visionary, dedicated, “will not quit” chiropractors, resulting in the first chiropractic programme in the world whose first exit point was a Masters degree.

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- Till, G(a). Personal communication with the persons mentioned over a number of years.
- Till, G(b). Personal recollections.

* The late Brian Peters served on PACA and CASA councils for about two decades, accumulating much documentation, including all previous council and general meetings minutes as per CASA Council (1981)". In the early 1990's, whilst I was HoD in Durban, I asked him to write a history of the profession, which he produced in 1993. It is the single, most comprehensive but unpublished collection of information on the subject that I am aware of.

** (CASA Council (1981) 'Item 7(a): Matters arising from the minutes'. *Minutes of the CASA Council meeting 8 February 1981*, Union Club Building, Johannesburg.

Excessively crying babies: A cross-sectional survey of sensory regulation difficulties in a South African chiropractic clinic

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ABSTRACT

Background: Although there has been extensive research on infant colic, nomenclature remains confusing as the term infant colic was commonly used as the diagnosis for the excessively crying baby with no evidence of aetiology or even subgroups.

Objectives: The aim of this pilot study was to investigate the prevalence of sensory regulatory difficulties among infants that have been diagnosed with colic in a single chiropractic practice and whether significant differences exist between excessively crying infants with sensory regulation difficulties versus other infants diagnosed with colic and whether this could be a potential subgroup of excessively crying babies.

Setting and subjects: Convenience sample of infants with colic who routinely presented to a single chiropractic practice in Johannesburg, South Africa between July 2015 and October 2015.

Methods: This was a cross-sectional study of infants who presented with a diagnosis of infant colic determined by their parents or other clinicians prior to entering this clinic. The study was conducted using the standardised sensory regulation screening tool (*Infant Toddler Sensory Profile*) in conjunction with a questionnaire developed by the researcher.

Results: Infants ($n=21$) that presented with colic were analysed. Results showed there was a significant difference with regards to crying ($p < .10$) between the subgroups of sensory sensitive and sensory seekers as well as low threshold and sensory seekers, respectively. This suggests that infants with sensory regulation difficulties and those with low threshold to sensory stimulus cry more than infants categorised as sensory seeking.

Conclusions: Although the small numbers limited the generalisability of the study, the aim of the trial was a pilot study to determine whether it is possible to categorize an infant with sensory regulatory difficulties with these tools. Excessive crying was linked to sensory sensitive and low threshold babies as compared to sensory seeking subgroups. This may assist with management strategies with excessive crying infants and is merely a first step toward further differential diagnosis of the excessively crying baby. A comprehensive differential diagnosis, risk factors and the natural progression of colic are yet required to lead to improved intervention guidelines. This small project may indicate that further research into these concepts could be fruitful in identification of further sub-groupings for infant colic.

INTRODUCTION

Although there has been extensive research on infant colic, nomenclature remains confusing as the term infant colic was commonly used as the diagnosis for the excessively crying baby with no evidence of aetiology or even subgroups. The aim of this pilot study was to investigate the prevalence of sensory regulatory difficulties among infants that have been diagnosed with colic in a single chiropractic practice and whether significant differences exist between excessively crying infants with sensory regulation difficulties versus other infants diagnosed with colic and whether this could be a potential subgroup of excessively crying babies.

Miller and Newell, (2012) categorised excessively crying babies into three subgroups: infant colic, irritable infant

syndrome of musculoskeletal origin (IISMO) and inefficient feeding crying infants with disordered sleep (IFCIDS) based on history and physical findings. Nevertheless, the diagnosis of IFCIDS remained nebulous, involving most infant behaviours but without an exact aetiology. This subgroup was less responsive to manual therapy than the other two identified conditions. These were seriously fussy babies that were considered to be inconsolable. De Gangi, (2000) lists self regulation symptoms as fussiness, paradoxical crying, disordered sleep, inability to self-calm, feeding issues, attention and arousal levels, mood regulation and inability to transition. The IFCIDS diagnosis describes the condition; however an accurate diagnosis is needed.

The characteristics of IFCIDS often coincide with sensory

regulation difficulties (Miller *et al.* 2005). Characteristics of the IFCIDS suggests the crying lasts up to twelve months and is associated with feeding issues and difficulties falling and staying asleep. Rosen, (2007) states that colic is a variant of infant irritability and could be a neural regulation disorder. Regulatory disordered infants can be described as behaviourally difficult, exhibiting disturbances in sleep, feeding, state control, self-calming and mood regulation (DeGangi *et al.* 1991). Barr, (1998) categorises excessive crying into four clinical crying “syndromes”: colic; persistent mother–infant distress syndrome; the temperamentally “difficult” infant; and the dysregulated infant. These are again, descriptions, not diagnoses or aetiologies, but they do give varied parameters of these infant’s problems. It seems that many researchers have identified the problem, but not the solution.

Sensory regulation problems in infants have been described as “fussy,” colicky or difficult-to-soothe children (De Gangi and Laurie, 1990; Maldonado *et al.* 1998; Reebye and Stalker, 2009). The process of sensory regulation suggests that infants are able to tolerate changes and self-soothe due to an “organised” neurological system (Biel and Peske, 2009). Sensory regulation is an important aspect of development that allows meaningful interactions with the environment. It is important to assess sensory dysregulation as the impact of early experiences on the developing brain cannot be overestimated (Reebye and Stalker, 2009).

Therefore identification and classification of a comprehensive differential diagnosis may improve clinician’s ability to accurately treat the excessively crying infant. The lack of understanding of the cause of excessive crying is related to the lack of consensus of the definition and management strategies. This can increase the stress and anxiety for the parents as they receive conflicting information. The literature provides inconsistent definitions, aetiology and management strategies; hence chiropractors are unable to provide consistent management plans for infants of distressed parents. Therefore the aim of this research was to improve clinicians understanding of an under-investigated condition, sensory regulation difficulties and investigate whether this may be one differential diagnosis for infant colic.

METHODS

Convenience sample of infants with colic who routinely presented to a single chiropractic practice in Johannesburg, South Africa between July 2015 and October 2015. This was a cross-sectional study of infants who presented with a diagnosis of infant colic determined by their parents or other clinicians prior to entering this clinic. The study was conducted using the standardised sensory regulation screening tool (*Infant Toddler Sensory Profile*) in conjunction with a questionnaire developed by the researcher.

Ethical approval was granted by the Faculty of Health Sciences Research Ethics Committee, University of Johannesburg (REC 01-255-2015).

RESULTS

Infants ($n=21$) that presented with colic were analysed. Results showed there was a significant difference with regards to crying ($p < .10$) between the subgroups of sensory sensitive and sensory seekers as well as low threshold and sensory seekers, respectively. This suggests that infants with sensory regulation difficulties and those with low threshold to sensory stimulus cry more than infants categorised as sensory seeking.

DISCUSSION

This study was an investigation into the behavioral characteristics of infants with colic and to determine the role of the sensory system in excessively crying infants. Subgrouping excessively crying infants is important in order to assist in treatment protocols and management. Due to the limited time to run the study, only a small sample was obtained; therefore, these results are indicative only and cannot be used to generalize to the wider colic population. Even so, a statistically significant difference occurred between the sensory subgroups in the study.

Another key finding not previously investigated was that there was no statistical difference between parent’s perception of colic (mother’s definition) and Wessels Criteria (Rule of Threes definition). This confirms what many studies have suggested previously, that parent/guardian reporting of crying or fussing problems are clinically relevant and that parents are excellent historians of their infant’s behaviours (Lehtonen and Rautava 1996; Wake *et al.* 2006).

Previous research has shown the highest correlation with excessively crying babies is assisted birth (Zwart *et al.*, 2010). All of the births in our study were assisted, a variant never previously reported in cry baby studies. Only two deliveries were vaginal with assistance; all of the rest were caesarean sections. Elective caesareans are cultural to urban Johannesburg, hence these results cannot be generalised. The World Health Organisation recommends a maximum of 15% caesareans per country (Gibbons, *et al.*, 2010). Figures released by South Africa’s Council for Medical Schemes showed that nearly 70% of births to women covered by a private medical scheme were by caesarean last year (Guardian, 2014). The numbers in this study exceed the national private medical aid scheme statistics and this may be due to the unique population that chooses their own health care, hence presenting to a chiropractic clinic. The types of birth in this study could be related to their cry baby presentation. Premature infants (less than 39 weeks (Committee Opinion, 2013)) showed frequent low threshold response when compared to infants born at full term (Muhlenhaupt, 2005). In South Africa, the majority of caesarean sections are done at 38 weeks. There is thus a possibility of borderline hypersensitivity or over-responsive behaviour in this sample.

Excessive crying in an infant may be an early indicator of sensory regulatory difficulties. That hypothesis triggered the use of the *Infant Toddler Sensory Profile* to subgroup the infants in this study.

Theoretically sensory sensitive and low threshold types can be grouped together because they both have low neurological thresholds. However in this study we separated the two subgroups as they also have clinically different presentations/behaviours. Our study was the first to compare the excessive crying of the sensory sensitive group versus sensory seeking and the low threshold group versus sensory seeking infants. There was a statistically significant difference between the subgroups.

The *Infant Toddler Sensory Profile* combined with a parent interview and clinical experience may provide information to help the parent respond to the infant's sensory needs. Inconsolability is often considered the hallmark of infant colic (Radesky, 2013). The ability to soothe a baby relates to their sensory profiles. Some mothers in this study used calming strategies more than others. Most parents/guardians reported having to rock/swing their infants to soothe them. Movement draws the infant back into the world of the womb, which has a calming effect on the infant (Faure and Richardson, 2002). Most of the infants in this study also used a dummy as a self-soothing mechanism. Just under half of mothers used feeding to console. Feeding is often considered an effective calming mechanism by parents (Howard, *et al.*, 2006).

Management strategies for cry babies should include parent education, which would differ between the sensory groups identified according to sensory profile. General management strategies bring the infant back to the world of the womb with calming strategies. Megan Faure (2015) groups sensory sensitive and low threshold together due to the infant's behaviours. Sensory sensitive and low threshold infants often present with colic, diagnosis of reflux, fussy eating, poor sleep, temper tantrums and separation anxiety; however they respond well to routine (Faure, 2015). In comparison, sensory seekers commonly present as busy babies, with poor sleep patterns, but are often developmentally advanced and engaging (Faure, 2015). Sensory seekers crave or seek sensory input (Williamson and Anzalone, 2001). Therefore sensory seekers usually respond well to deep pressure, movement and other soothing techniques. Sensory sensitive and low threshold infants need to be soothed to maintain a calm-alert state (Faure, 2011). What this implies is implementing changes in environmental factors in the room (light, noise), therapist handling of the baby (less movement versus more movement, warm hands as opposed to cold hands, voice tone) and finally assisting parent/guardian to understand the infant and the management plan. Parent education allows the parents to understand their infant's early warning signals and empowers them to incorporate calming strategies into their day, rather than wait for the need once the child's crying is set off.

Infants that haven't responded to the parent's management and calming strategies may require further intervention. Referral to a sensory integration trained occupational therapist is then advised. The occupational therapist may introduce a home sensory program i.e. sensory diet. Sensory

diets are specifically tailored activities to allow the infant to remain in a calm-alert state. The purpose is to ensure optimal bonding (for the infant and parents) and development. Early intervention prevents long-term impact of sensory regulatory difficulties and the possible impact of behavioural and functional difficulties (Faure and Du Plessis, 2009).

This study suggests cry babies need to be assessed for sensory regulatory difficulties to prevent any potential long term consequences. Long-term sequelae are most likely as an infant's development relies heavily on sensory input. Studies conducted by Rautava *et al.* (1995), Jacobsen and Melvin, (1995), Canivet *et al.* (2000), von Kries *et al.* (2006) and Neu, (1997) all suggest long term sequelae of excessive crying. Hence professionals and parents need to understand infant's behaviours within a sensory processing context (Dunn and Daniels, 2002). Integration of all sensory systems is necessary for gross motor development so early intervention may be the key to prevention.

Other studies can now be re-examined in light of these findings. My hypothesis is that the Inefficient Feeding Crying Infant with Disordered Sleep (IFCIDS) (Miller and Newell, 2012) have low thresholds and therefore minimal input can overwhelm or over stimulate the infant. In the Miller study, it was pointed out that the IFCIDS classification didn't respond to manual therapy. Although there was no long-term follow-up of IFCID cases, it is well known that chronic excessive crying has very poor outcomes even up until middle to later childhood (Wolke, *et al.*, 2002). These could possibly be the infants with sensory regulatory difficulties.

The attempt of their study was to start a dialogue that could lead to consensus in the use of more precise terminology for the cry baby. The aim of this trial was a pilot study to determine whether it is possible to categorise colic infants with sensory regulatory difficulties with these tools. It is merely a first step toward further differential diagnosis and subgrouping of the excessively crying baby.

CONCLUSIONS

Although the small numbers limited the generalisability of the study, the aim of the trial was a pilot study to determine whether it is possible to categorize an infant with sensory regulatory difficulties with these tools. Excessive crying was linked to sensory sensitive and low threshold babies as compared to sensory seeking subgroups. This may assist with management strategies with excessive crying infants and is merely a first step toward further differential diagnosis of the excessively crying baby. This study also found that mother's diagnosis of colic was clinically relevant when compared to Wessel's Criteria. Subgrouping could help clinicians to understand excessively crying babies as well as to help mothers regulate the baby's sensory systems. A comprehensive differential diagnosis, risk factors and the natural progression of colic are yet required to lead to improved intervention guidelines. This small project may indicate that further research into these concepts could be

fruitful in identification of further sub-groupings for infant colic.

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The role of a chiropractor in identification of acral lentiginous melanoma: A case report

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ABSTRACT

Melanoma is widely known disease that affects many South Africans every year. Acral lentiginous melanoma (ALM) is subtype of cutaneous melanoma that affects the acral skin: the soles, palms and sub-ungual regions. ALM has a poor prognosis when compared to other melanoma types due to late detection. ALM has a higher risk profile in population groups of African and Asian ancestry and therefore needs to be kept in mind in the context of South Africa. Although diagnosis may require biopsy, it is important for chiropractors to be aware of such lesions and refer appropriately when concern arises. Many chiropractors may not be aware of this cutaneous melanoma subtype and this paper serves to draw attention to it.

INTRODUCTION

A melanoma is form of cutaneous cancer of the pigmented cells, melanocytes, within skin. Acral lentiginous melanoma (ALM) is subtype of cutaneous melanoma that affects the acral skin: the soles, palms and sub-ungual regions (Hudson and Krige, 1993). It is a melanoma found in areas of low-level-exposure to sunlight (Bristow, and Acland, 2008). Although it is the rarest of the four sub-types of cutaneous melanoma, it is the most common variety diagnosed on the foot (Bristow, and Acland, 2008; Hudson, Krige, and Stubbings, 1998). ALM represents the most common type melanoma of dark skinned peoples of Asian and African-ancestry (Badge, Meshram and Ovhal, 2015; John, Hayes Jr, Green and Dickerson, 2000). In a South African context, the population at highest risk of developing ALM represents 46 million individuals (Statistics South Africa, 2016). Due to late detection ALM has a poor prognosis when compared to other cutaneous melanoma types (Piliang, 2011; Gumaste, Penn, Cohen, Berman, Pavlick, and Polsky, 2015; Hudson *et al.* 1998; Krige, 2010). Although diagnosis may require biopsy, it is important for chiropractors to be vigilant and aware of such lesions so that referral can be made appropriately and timeously when concern arises. Many chiropractors may not be unaware of this melanoma subtype and this paper serves to draw attention to it. One of the most well-known people to have died from ALM is Bob Marley.

CASE PRESENTATION

A 35-year-old male of African-ancestry presented to the author's practice with low back pain, radicular in nature, down the left leg. Treatment required the patient to lie in the prone position with his shirt, shoes and socks removed. General inspection revealed a pigmented area of skin on left lateral foot near the calcaneus. The man was unaware

the lesion existed and he had no recollection of how long it had been present. The lesion had a mottled appearance of dark brown and black pigmentation with predominance of pigmentation in a parallel ridge-like pattern (see [Figure 1](#)). Diagnosis was accomplished through histopathological assessment.

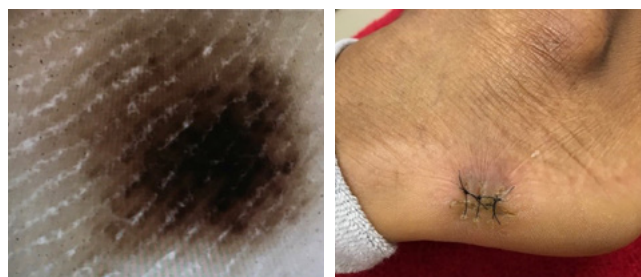


Figure 1: (left) Macroscopic view of ALM in-situ under 10x magnification, (right) site of the lesion post-surgical excision.

HISTOLOGY

Macroscopic description: the excised specimen measured 20x10x4mm with the ALM measuring 7x7mm.

Microscopic description: Histologic examination of the initial sections and further levels demonstrated the presence of a very EARLY ACRAL MELANOMA IN SITU (microphotograph [Figure 2](#)). This is composed of a proliferation of atypical melanocytes which are present within the basal layer of the epidermis (microphotograph [Figure 3](#)). Most tellingly, melanin pigment columns extending through the corneal layer in relation to the intra-corneal coiled eccrine ducts, for the most part, opening onto surface ridges (microphotograph [Figure 4](#)).

The ALM in-situ has been completely excised – 1,32mm from the nearest peripheral margin.

There was no invasive malignancy.

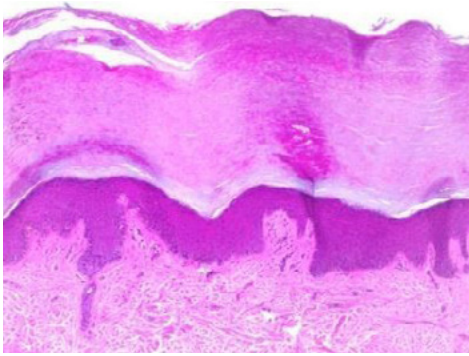


Figure 2

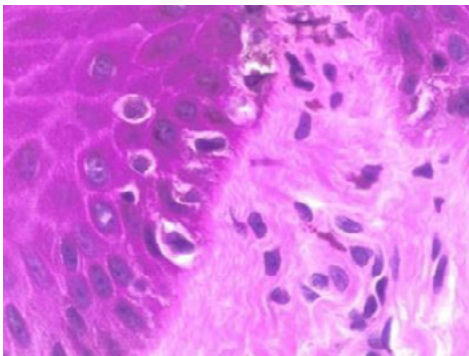


Figure 3

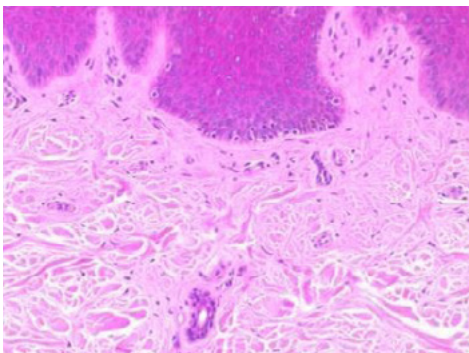


Figure 4

MANAGEMENT AND OUTCOME

The differential diagnosis of acral pigmentation consists of benign and neoplastic. Benign differentials include: melanocytic nevus and talon noir while neoplastic differential includes melanoma and specifically ALM. Due to the pigmentation pattern and uncertainty as to the length of time present, referral to a dermatologist for further evaluation was sought. Dermoscopy demonstrated a parallel ridge-like pattern of pigmentation which is a characteristic of melanoma (Hudson *et al.* 1998; Ishihara, Saida, Miyazaki, Koga, Taniguchi, Tsuchida, Toyama and Ohara, 2006; Tanaka, 2013), (see [Figure 1](#)). Biopsy and histological examination was elected for further investigation (see histology). Current treatment guidelines for ALM in situ differ. Generally 5mm is an accepted margin of clearance with some studies indicating 6-9mm margin of clearance is necessary (Nakamura, Teramoto, Sato and Yamamoto, 2015). No radiation therapy is necessary for ALM in situ (Nakamura, 2013). Following

the histopathology diagnosis the patient was advised to re-perform surgical debridement of tissue to increase the margin of clearance necessary for a curative intervention.

The prognosis of ALM is directly related to the stage at which it is found, providing margins of clearance are adhered to when removal occurs.

DISCUSSION

Skin anatomy and terminology

Due to important function of grip, acral skin of the palms and soles are arranged in parallel ridges and furrows (Ishihara *et al.* 2006; Kaminska-Winciorek, and Spiewak, 2012). These elevations and depressions may resemble the gross appearance of agriculture farmland layout (see [Figure 5](#)).

When pigmentation is present, knowing the surface anatomy of skin may indicate possible aetiology (Braun, Thomas, Kolm, French and Marghoob; 2008; Tanaka, 2013). Most benign lesions have a distribution of a furrow pattern or lattice pattern of pigmentation (Tanaka, 2013), (see [Figure 5](#)).

The most sensitive sign for ALM is a parallel ridge pattern: this is a pattern of pigmentation primarily contained within the surface ridges (Ishihara *et al.* 2006; Braun *et al.* 2008).

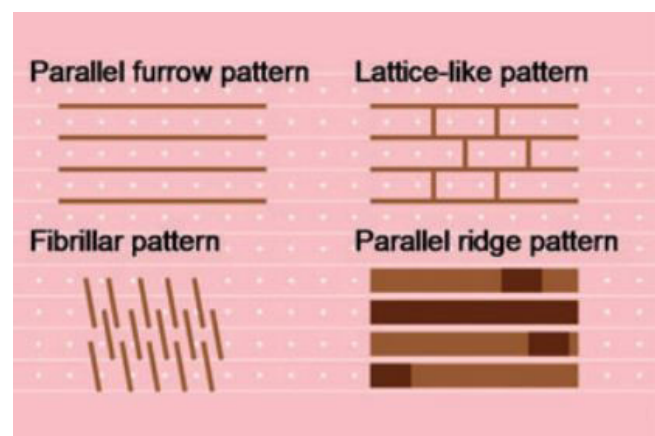


Figure 5: The four basic dermoscopy patterns in acral melanocytic lesions (Tanaka, 2013). Note: the white dots illustrated correspond with crista superficialis: eccrine ducts opening at the surface of the skin.

Distribution of melanoma in South Africa

The South African population statistics survey (2016) estimated race groups in South Africa consisting of 'Black African' at 80.7%, 'Coloured' at 8.7%, 'White' at 8.1% and 'Indian/Asian' at 2.5% of the total population (Statistics South Africa, 2016). As ALM represents the most common type melanoma of dark skinned peoples of Asian and African-ancestry, the statistics indicate the population groups at highest risk of development will constitute 83.2% of the total population. This represents 46 million people of the total 55 million population (Badge *et al.* 2015; John *et al.* 2000; Statistics South Africa, 2016).

In the European-ancestry/fair-skinned population, more than 90% of melanomas occur in sun-exposed areas, whereas, 60% of melanomas occurring in the African-ancestry population are found in low to low-sun-exposed regions of the body. These low-sun-exposed areas include the palms, soles and sub-ungual regions and the mucosa. The most common anatomical sites for melanoma in the African-ancestry population are the volar and sub-ungual areas (Isaacson and Spector, 1987; Hudson and Krige, 1995; Krige, 2010).

Interestingly 70% of the melanomas in the African-ancestry population occurring elsewhere on the body are found on the lower limb and 90% of these are found below the ankle (Isaacson and Spector, 1987; Hudson and Krige, 1995; Krige, 2010).

The most common sub-type of melanoma, ALM, accounts for 75% of melanomas seen in the African-ancestry population group (Hudson and Krige, 1993; Isaacson and Spector, 1987; Hudson and Krige, 1995; Krige, 2010). The incidence of melanoma in the African population is 15 times lower than that of the any other population group; it is often seen more frequently with advanced local disease and metastatic spread when compared to European and mixed-ancestry groups (Hudson *et al.* 1998; Hudson and Krige, 1995). According to Hudson *et al.* (1998) nearly half of the ALM patients of African-ancestry presenting to Groote Schuur Hospital, Observatory, Cape Town, over a 14 year period had disseminated disease (Hudson and Krige, 1993; Isaacson and Spector, 1987; Hudson and Krige, 1995; Krige, 2010). Furthermore, the 5 year survival rate of the African population group was 26% compared to 60% for European population and 24% for those of mixed ancestry (Hudson *et al.* 1998).

CONCLUSION

Acral lentiginous melanoma is likely to be seen in private practice. Due to the large population size of high risk individuals, it is a condition which should be kept in mind when performing general inspection especially of the lower limb and foot. Chiropractors have a responsibility to be vigilant. Early diagnosis of melanomas will significantly improve prognosis, especially in the case of ALM. Awareness campaigns should be targeted at both health care providers as well as the general population. When suspicion arises referral out in a timely manner is important.

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The effect of spinal manipulation on biceps brachii muscle activity

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ABSTRACT

Objectives: This study investigated whether spinal manipulation of the ipsilateral C5/C6 segment facilitates linear summation of golgi tendon organ Ib afferent activity of the biceps brachii muscle as part of the convergent input on homonymous motor neuron pool excitability.

Methods: This placebo-controlled, single-blind, repeated measures study employed asymptomatic sample ($n = 20$) investigating two conditions: Activator Adjusting Instrument placebo spinal manipulation and spinal manipulative therapy.

Results: The immediate post-spinal manipulation therapy revealed a decrease in the biceps muscle electromyography Root Mean Square by 9.03 % ($p = 0.39$) in the face of an increase in biceps muscle force by 4.76 % ($p = 0.155$). Previous studies showed improved functional capacity of the homonymous muscle post-spinal manipulation. The presumed mechanism is a decrease in arthrogenic muscle inhibition through uncertain neural mechanisms. This study showed that C5/C6 spinal manipulation may facilitate biceps muscle autogenic inhibition, and suggests that through repeated spinal manipulation over time and the resulting habituation, altered arthrokinetic spinal reflex arcs caused by raised A β -fiber afferent discharge from somatic receptors in facet joint tissue may be desensitized with subsequent improved α -motor neuron functioning.

Conclusions: This study suggests a neural mechanism underlying the beneficial effect of spinal manipulation on arthrogenic muscle inhibition and α -motor neuron functioning in the symptomatic and asymptomatic individual. However, given the small sample size and large standard deviation, further research is warranted to add statistical significance to this finding.

INTRODUCTION

Spinal manipulation or known as spinal manipulative therapy (SMT) is a high-velocity low-amplitude (HVLA) thrust delivered at the end range of motion of facet joints in the spine, in the direction of the orientation of the facet joint articulation, often accompanied with an audible cracking sound (Millan *et al.*, 2012; Pickar, 2002). One of the most foremost theories for the neurophysiological mechanism underlying SMT entails the reduction of central sensitization. Central sensitization has been postulated to induce abnormal spinal reflex arcs which can affect the homonymous motor, nociceptive and possibly the autonomic neuronal pools by sensitizing mechano-insensitive nociceptors within and around the facet joint tissue (Olsen, 2015; Vernon, 2010). SMT is believed to correct alterations in the anatomical, physiological and / or biomechanical dynamics of individual vertebral segments which lead to the induction of the central sensitization, also known as the chiropractic subluxation complex, to its pre-injury / normal state, and in doing so restores the normal functioning of the nervous system (Gatterman, 2005; Pickar, 2002). However, the exact underlying neurophysiological effect of SMT on motor activity is uncertain and there is a lack of knowledge in the literature regarding its effects on asymptomatic individuals.

The electromyographic (EMG) response post-SMT may elucidate the neurophysiological effect of SMT on motor activity (Olsen, 2015; Pickar, 2002). Although many studies have showed that SMT can alter the excitability of the homonymous motor neuron pool and evoke spinal reflex activity (Olsen, 2015; Pickar, 2002), the literature shows conflicting evidence regarding the excitatory or inhibitory nature of the reflexive EMG response and excitability of the homonymous motor neuron pool post-SMT (Dunning and Rushton, 2009; Olsen, 2015). The immediate EMG response post-SMT entails an initial latent period consisting of a few milliseconds in duration followed by a transient increase in EMG amplitude, or, solely, a transient decrease in the EMG amplitude or decrease in the excitability of the homonymous motor neuron pool (Olsen, 2015; Pickar, 2002). The neural mechanism responsible for the EMG response latency occurring immediately post-SMT is largely unknown (Pickar, 2002). Several studies in the literature have postulated that a decrease in arthrogenic muscle inhibition (AMI) through either facilitation or disinhibition of the involved neural pathways is responsible for the transient increase in EMG amplitude and improved functional capacity of the homonymous muscle post-SMT (Dunning and Rushton, 2009; Suter and McMorland, 2002).

From a neurophysiological perspective, the literature has not yet linked the stimulatory effect of SMT on mechanoreceptors (type I-III nerve ending / somatic receptors) in the facet joint tissue with AMI; an increased discharge of A β -fiber afferents from mechanoreceptors in joint tissues causes Ib inhibition on the homonymous motor neuron pool, in the presence and absence of pain (Konishi *et al.*, 2003; Rice and McNair, 2010). Furthermore, although occupational and physical therapists use the principles behind habituation (neuroplasticity) to decrease abnormal neural responses to a stimulus by using specific techniques and exercises based on the effects of habituation, such as in the treatment of hyperesthesia (Lundy-Ekman, 2013), the concept of SMT achieving habituation to abnormal arthrokinetic spinal reflex arcs is not evident in the literature. This study investigated whether ipsilateral C5/C6 SMT facilitates linear summation of golgi tendon organ (GTO) Ib afferent activity (autogenic inhibition) of the biceps brachii muscle as part of the convergent input on the homonymous motor neuron pool excitability.

METHODS

Subjects

A convenience sample of 20 individuals asymptomatic for neck pain and bilateral upper extremity pain who presented himself or herself to the Durban University of Technology Chiropractic Day Clinic (8 females and 12 males) with a mean age of 26 ± 3.3 years was recruited. Only subjects between the ages of 18 and 40 were selected. Screening questions for the exclusion criteria and the clinical presence of any contraindication for cervical SMT (Puentedura *et al.*, 2012: 66) or any indication for further special investigations during a thorough case history, physical examination, and cervical spine regional examination were negative. This study was approved by the Institutional Research Ethics Committee of the Durban University of Technology (IREC Reference Number: REC I I I / 1 5), and written informed consent was obtained from all the subjects prior to the testing.

Equipment

Active EMG and dynamometry recording of the biceps muscle were made using the Bionomadix® (Biopac) complete wireless research system with four channel EMG recording, and TSD121C (Biopac) isometric hand dynamometer (0 kg to 100 kg) and amplifier. EL509 (Biopac) detection electrodes were made of Ag/AgCl laminated carbon with incorporated electrode gel cavity (16 mm diameter and 1.5 mm deep) in the form of parallel bars 27 mm long and 36 mm wide with inter-detection surface spacing of 1.0 cm. The full frequency spectrum of the biceps muscle EMG signal between 20 Hz and 450 Hz was captured (Dunning and Rushton, 2009: 509; Suter and McMorland, 2002). An- II Activator Adjusting Instrument (AAI) (Activator Methods) with a force setting

of zero force was used to deliver an AAI placebo SMT (Humphries *et al.*, 2013).

Procedure

Each subject was instructed by the researcher to sit on a chair in front of an adjustable small table and to place his or her arm on the table. The adjustable table was set so that the subject's arm was horizontal to his or her shoulder. The subject's elbow was extended and the forearm supinated passively. The extended elbow remained in contact with the table and the distal supinated forearm hung off the table. The researcher correctly identified the C5/C6 spinal level by using specific palpation techniques (Benzel, 2012; Magee, 2008). The C5/C6 spinal levels were marked clearly on each subject's skin using a non-permanent marker pen. The proper skin preparations were administered over the biceps muscle at the sites of the EMG electrode placement (Dunning and Rushton, 2009; Quach, 2007) before placing the electrodes correctly onto the biceps muscle (De Luca, 2002; Quach, 2007). The reference EMG electrode (27 mm x 36 mm) was placed on the posterior aspect of the ipsilateral deltoid muscle of each subject.

Thereafter each subject performed three sets of modified stretching of the biceps muscle based on the principles of the autogenic inhibition phase of proprioceptive neuromuscular facilitation (PNF) stretching. All three sets of modified stretching were 10 seconds in duration with two minute rest intervals and occurred in a single appointment. Before each set started, a 10 mm by 2 m tie down strap was strapped to the distal forearm of each subject by the researcher. The pull side of the TSD121C hand dynamometer 100 kg was attached to the tie down strap. A second 10 mm by 2 m tie down strap was used to attach the push side of the dynamometer to a 1 kg plate, which hung below the distal forearm of the subject (Figure 1). The dynamometer was then correctly calibrated with the attached 1 kg plate.

The weight of the 1 kg plate fully extended the elbow and passively stretched the biceps muscle to elicit the autogenic excitation phase of the modified stretching. The subjects were then instructed by the researcher to "resist against the weight of the 1 kg plate for 10 seconds without bending your elbow" to perform an isometric contraction of their biceps muscle and thereby to elicit the autogenic inhibition phase of the modified stretching. The subject's elbow must have remained stationary to hold the biceps muscle in a passively stretched position. The subjects were also instructed beforehand to "maintain the same constant biceps muscle contraction as possible for the whole duration of the 10 seconds of resistance" to rule out unwanted additional voluntary effort by the subjects. The raw EMG and dynamometry readings were recorded simultaneously during the entire duration of biceps muscle activity of each set of modified stretching. After the 10 seconds of resistance of each set, the tie down strap with the attached dynamometer and 1 kg plate was temporarily removed from the subject's distal forearm by the

researcher during the rest periods. The EMG electrodes were not removed from the subject's biceps muscle during the rest periods.



Figure 1: The setup of the modified stretching of the biceps muscle based on the principles of the autogenic inhibition phase of PNF stretching.

During the first set (AAI 1 intervention) and second set (AAI 2 intervention) of modified stretching, at the 4th second an AAI placebo SMT was correctly administered to the ipsilateral C5/C6 segment (Humphries *et al.*, 2013: 153). Although the AAI was set to a force setting of zero, the AAI placebo SMT still caused an audible cavitation type sound (Humphries *et al.*, 2013: 153). The researcher removed the contact of the AAI from each subject's skin immediately after the interventions. AAI placebo SMT cannot stimulate mechanoreceptors in the facet joint tissue (Huggins *et al.*, 2012: 53; Humphries *et al.*, 2013: 153) and may therefore have no effect on the linear summation of GTO Ib afferent activity of the biceps muscle during the modified stretching as part of the convergent input on the homonymous motor neuron pool excitability.

During the third set (SMT intervention) of modified stretching, at the 4th second the researcher correctly locked up the ipsilateral C5/C6 facet joint prior to administering the standardized posterior-to-anterior HVLA thrust at the 6th second (Bergmann and Peterson, 2010; Redwood and Cleveland, 2003). A two second time interval was given in order to lock up the C5/C6 facet joint. The researcher then re-positioned the participant's head to the starting position and removed any contact by the researcher from each subject immediately. The C5/C6 SMT can stimulate mechanoreceptors in the facet joint tissue (Dunning and Rushton, 2009; Olsen, 2015) and may therefore have an effect on the linear summation of GTO Ib afferent activity of the biceps muscle during the modified stretching as part of the convergent input on the homonymous motor neuron pool excitability.

Data and statistical analyses

The MP 150 data acquisition system and AcqKnowledge® analysis software was used to capture one-second EMG

segments during the entire force plateau of each set of the modified stretching of the biceps muscle. The raw EMG signal was processed through Root Mean Square (RMS) analysis and the dynamometer data by the MP 150 data acquisition system and AcqKnowledge® analysis software, to obtain the variables of biceps muscle EMG RMS and force. Objective analyses made use of the mean values of each variable for the 500 millisecond period before and after, at the 4th second for the AAI 1 and AAI2 interventions and at the 6th second for the SMT intervention, during each set of modified stretching. These values were also subtracted from one another to calculate change scores for each variable. This process resulted in 120 biceps muscle EMG RMS and 120 biceps muscle force means in total encompassing a pre- and post-values for the AAI and SMT conditions. The mean percentage of change (Dunning and Rushton, 2009) in active biceps muscle activity for the variables was calculated.

Bivariate analyses consisted of independent t-tests, adjusted for unequal variance where appropriate. All analyses were performed with a confidence interval of $\alpha = 0.05$, as well as an optimal alpha (α) to account for the lack of power inherent in small sample designs as per Mudge *et al.*'s (2012) recommendations. The optimal α s were determined separately for the two sample comparisons between the AAI 1 and AAI 2 interventions; optimal $\alpha = 0.232$, and those between the SMT intervention and both AAI interventions (AAI 1 + AAI 2), optimal $\alpha = 0.203$. The calculation optimized α to find a medium effect size of $d = 0.5$ which was an equal weight for the cost of errors and a prior probability ratio of 1. The optimal α for the AAI intervention comparison yielded a power of 0.647, a large improvement from that of the conventional α , power = 0.338. Similarly, the optimal α for the SMT intervention and AAI interventions (AAI 1 + AAI 2) comparison yielded a power of 0.707, a large improvement from that of the conventional α , power = 0.429.

RESULTS

The 60 interventions applied to the 20 participants compromised 20 SMT interventions (33.3 %) and 40 AAI interventions (66.7 %). For the AAI interventions, 40 experienced an audible cavitation (100 %) and null experienced a non-audible cavitation (0 %). For the SMT interventions, 17 experienced an audible cavitation (85 %) and 3 experienced a non-audible cavitation (15 %).

The mean scores of the immediately pre- and post-AAI 1 and AAI 2 interventions are fairly similar across the variables for biceps muscle EMG RMS and force (Table 1). While differences are present between the AAI 1 and AAI 2 interventions, they are generally much smaller than the differences between them and the immediately pre- and post- SMT intervention, although the standard deviation of the variables in relation to the differences between the interventions is also fairly large (Table 1). The AAI 1 and AAI 2 interventions show a decrease in the biceps muscle EMG RMS along with a decrease in biceps muscle force,

Table 1: The EMG RMS and muscle force of the biceps brachii immediately pre- and post-interventions ($M \pm SD$)

	Baseline (500 ms pre-intervention)	Post-intervention (first 500 ms)	Percentage difference (%)	
RMS (μV)				
Placebo AAI 1	41,98 \pm 20,83	41,21 \pm 20,27	1.86	$p = 0.39$
Placebo AAI 2	37,41 \pm 20,19	37,4 \pm 22,36	0.05	
SMT	49,53 \pm 23,48	45,25 \pm 23,93	9.03	
Force (kg)				
Placebo AAI 1	2,397-1 \pm 2,238 ⁻²	2,377-1 \pm 2,304 ⁻²	0.85	$p = 0.155$
Placebo AAI 2	2,369-1 \pm 2,153 ⁻²	2,323-1 \pm 2,162 ⁻²	1.97	
SMT	2,327-1 \pm 3,69 ⁻²	2,440-1 \pm 5,419 ⁻²	4.76	

whereas the SMT intervention reveals a decrease in biceps muscle EMG RMS and an increase in the biceps muscle force immediately post-interventions (Table 1).

In an analysis of the similarity of biceps muscle EMG RMS between the AAI 1 and AAI 2 interventions, no significant difference was found at both a conventional α level, $t(38) = 0.5344$, $p > 0.05$ ($p = 0.5962$), and an optimal α level, $t(38) = 0.5344$, $p > 0.232$. In an analysis of the difference in biceps muscle EMG RMS between the AAI interventions (AAI 1 + AAI 2) and the SMT intervention no significant difference was found at a conventional α level, $t(57) = 0.881$, $p > 0.05$ ($p = 0.3895$), or an optimal α level, $t(57) = 0.881$, $p > 0.203$. In an analysis of the similarity in biceps muscle force between the AAI interventions (AAI 1 + AAI 2) and the SMT intervention no significant difference was found at the conventional α level, $t(57) = 1.482$, $p > 0.05$ ($p = 0.1549$), but displayed a difference at the optimal α level, $t(57) = 1.482$, $p < 0.203$.

DISCUSSION

Proprioceptive neuromuscular facilitation stretching is the most effective stretching technique to increase muscle flexibility and range of motion, and is commonly used in the athletic and clinical environments (Sharman *et al.*, 2006). The underlying neural mechanisms involving PNF stretching consist of: firstly, autogenic excitation phase by way of facilitation of the Ia muscle spindle spinal reflex arc (gamma loop); secondly, autogenic inhibition phase by way of facilitation of the GTO Ib inhibitory di-synaptic spinal reflex arc; and thirdly, reciprocal inhibition phase via facilitation of the Ia inhibitory spinal pathways as a result of contraction of the antagonist muscle group (Bandy and Sanders, 2007; Sharman *et al.*, 2006). The autogenic inhibition phase of PNF stretching is performed by placing the targeted muscle passively in a lengthened position followed by an active low force muscle contraction for several seconds to activate the Ib afferent maximally (Bandy and Sanders, 2007; Sharman *et al.*, 2006). Many studies have demonstrated that the reduced efferent (motor) drive to the muscle by way of autogenic inhibition is a major factor that assists in elongation of the

targeted muscle (Sharman *et al.*, 2006; Umphred *et al.*, 2013).

Historically the function of the GTO was thought to be a protective reflex in which a strong and potentially damaging muscle force from excessive loading will reflexively inhibit the muscle by way of the autogenic inhibition, to cause lengthening of the muscle instead of trying to maintain the muscle force and risking damage (Khurana, 2014; Lundy-Ekman, 2013). Although the GTO provides some protection by way of the autogenic inhibition and has been shown to facilitate decreased excitability of the homonymous motor neuron pool, the role of the GTO resides more in supplying the central nervous system with sensory information regarding active muscle tension and thus force in the muscle generated, via their Ib afferent fibers (Khurana, 2014; Lundy-Ekman, 2013). The effect of GTO input to the homonymous motor neuron pool is not on its own powerful enough to inhibit voluntary muscle contraction by way of the lateral corticospinal tract (LCST, pyramidal motor pathway), because recent studies have affirmed that maximal GTO Ib afferent activity occurs before 50% of maximal voluntary muscle contraction (FitzGerald *et al.*, 2012; Lundy-Ekman, 2013). A protective reflex for a skeletal muscle is considered to be predominantly provided by the LCST which causes presynaptic inhibition of the homonymous actively stretched prime mover muscle spindle afferents close to the contact points with their α motor neurons by way of the interpolation of inhibitory interneurons in the intermediate grey matter of the spinal cord (FitzGerald *et al.*, 2012).

The behaviour of GTOs demonstrates an immediate response to muscle tension and consists of an initial dynamic response – a burst in GTO discharge within 0.5 seconds. A static response immediately follows and consists of a gradual decline to a constant GTO discharge (Mileusnic and Loeb, 2006; Plowman and Smith, 2007). Historically it was thought that GTOs only respond to high forces but several studies have demonstrated that the activation of multiple motor units simultaneously, such as during high muscle force output, cause the GTOs to demonstrate non-linear summation and produce Ib afferent activity that is smaller compared to the activation of a single or two motor units over time. Studies

have affirmed that the activation of a single or two motor units such as during very low muscle force output, causes the GTOs to demonstrate linear summation and produce higher Ib afferent activity (Mileusnic and Loeb, 2006; Sharman *et al.*, 2006). Although the GTO behaviour depends on the generated muscle tension that the extrafusal muscle fibers of the motor unit exert on the loosely packed innervated collagen fibrils found inside the lumen of the GTO, the response of the GTO also depends on the type of motor unit being activated (Mileusnic and Loeb, 2006).

Motor unit recruitment as well as the firing frequency of lower motor neurons (alpha/ α motor neurons and gamma/ γ motor neurons) are entirely dependent on the level of force and speed of muscle contraction by the voluntary effort of an individual (LCST), in the normal non-pathological state (Lundy-Ekman, 2013; Merletti and Parker, 2004). A direct relationship thus exists between the motor unit recruitment frequency and the homonymous muscle's generated force in relation to the voluntary effort of the individual (Lundy-Ekman, 2013; Merletti and Parker, 2004). A low force muscle contraction will cause the recruitment of low-threshold motor units with at least one of their extrafusal muscle fibers inserting into a GTO and intertwining with the loosely packed innervated collagen fibrils inside the GTO, resulting in linear summation of Ib afferent activity. As the muscular force becomes higher / faster by the voluntary effort of the individual, so the higher-threshold motor units will be recruited with at least one of their extrafusal muscle fibers inserting into a GTO and intertwining with the loosely packed innervated collagen fibrils inside the GTO, resulting in more non-linear summation of Ib afferent activity (Mileusnic and Loeb, 2006). Because the wiring of the α motor neuron entails multiple spinal segmental and supraspinal inputs, a single input may be insufficient to trigger the firing threshold of the homonymous α motor neurons and may solely influence the excitability of them. The summate balance between all these influences may decide if the homonymous α motor neurons increase or decrease their discharge frequency or excitability (Mense and Gerwin, 2010).

Linear summation of biceps muscle GTO Ib afferent activity may produce inhibitory post-synaptic potentials (IPSPs) in the homonymous α motor neurons and thereby solely decrease the excitability state of the homonymous motor neuron pool (Bandy and Sanders, 2007: 59; Mileusnic and Loeb, 2006) that facilitates the elongation of the biceps muscle during the modified stretching in this study (Sharman *et al.*, 2006; Umphred *et al.*, 2013). A decrease in the biceps muscle EMG amplitude (RMS) along with a decrease in biceps muscle force may result (Lundy-Ekman, 2013; Merletti and Parker, 2004). The results of this study supports the notion of the autogenic inhibition phase of PNF stretching reducing the efferent drive to the homonymous muscle; both the placebo SMT groups (AAI and AAI 2 interventions) showed a mean decrease in biceps muscle EMG RMS by less than 1.87 % and a mean decrease in biceps muscle force by less

than 1.98 % (Table 1). No significant difference was found between the placebo SMT groups.

The C5/C6 SMT showed a much larger difference than the placebo SMT groups for the EMG RMS and muscle force of the biceps muscle immediately pre- and post-interventions (Table 1). To the contrary, this large difference could not be quantified in terms of statistical significance due to the large standard deviation of the variables relative to the differences between the interventions and possibly due to the small population group (Table 1). The immediate post-C5/C6 SMT revealed a mean decrease in the biceps muscle EMG RMS of 9.03 % ($p = 0.39$) in the face of a mean increase in the biceps muscle force of 4.76 % ($p = 0.155$) and a summation of percentage difference between the biceps muscle force and EMG RMS of 13.79 %; the immediate post-placebo SMT groups showed a summation of percentage difference between the biceps muscle force and EMG RMS by less than 1.93 % (Table 1). This finding is noteworthy because the variables of EMG RMS and muscle force are also entirely dependent on the voluntary effort of the subject (Lundy-Ekman, 2013; Merletti and Parker, 2004).

The large standard deviation (Table 1) is possibly caused by each subject contracting their biceps muscle at their own intensity by their free will. The variables of biceps muscle EMG RMS and force could therefore not be standardized by depending on the subjects to perform a constant low force contraction of the biceps muscle during the modified stretching to rule out unwanted voluntary effort (Lundy-Ekman, 2013; Merletti and Parker, 2004). This is problematic because an increase in voluntary effort by the subjects during the modified stretching of the biceps muscle can cause the same EMG response post ipsilateral C5/C6 SMT: an increase in voluntary contraction of the biceps muscle by way of the LCST will cause an increase in both the biceps muscle EMG RMS and force (Lundy-Ekman, 2013; Merletti and Parker, 2004); Suter and McMorland (2002) found a transient increase in biceps muscle EMG RMS and force immediately post-C5/C6 SMT. A subconscious adjustment in voluntary effort by the mean subject could have been the mechanism responsible for the increase in biceps muscle force immediately post the C5/C6 SMT, due to an emotional component such as fright, excitement or fear experienced (Engelhardt *et al.*, 2001; Rice and McNair, 2010). A significant difference in biceps muscle force was found between the placebo SMT groups and the C5/C6 SMT at the optimal α level, $t(57) = 1.482$, $p < 0.203$ immediately post-interventions.

The anomalous decrease in biceps muscle EMG RMS during an increase in biceps muscle force observed immediately post the C5/C6 SMT is theoretically due to the spatial summation of combined, peak linear / non-linear biceps muscle GTO Ib afferent activity caused by the modified stretching and possibly an increase in voluntary effort by the mean subject, plus the transient increase in facet joint mechanoreceptor A β -fiber afferent activity caused by the stimulatory effect of the C5/C6 SMT; that produced the

transient summation of Ib inhibition on the homonymous α motor neurons that was larger than the summation of excitation produced by the LCST innervating the biceps muscle α motor neurons. As part of the convergent input on the α motor neurons innervating the biceps muscle; the C5/C6 SMT caused transient facilitation of the vertebral segment's facet joint Ib inhibitory spinal pathway(s) and thereby facilitated (reinforced) the autogenic inhibition of the biceps muscle (facilitated GTO Ib inhibitory di-synaptic spinal reflex arc) produced by the modified stretching, which resulted in sufficient IPSPs in the biceps muscle α motor neurons that drove the membrane potential at the axon hillock of each depolarized biceps muscle α motor neuron away from firing threshold and thereby prevented the LCST from transiently generating sequential action potentials in the biceps muscle α motor neurons. When the stimulus is removed that caused the generation of excitatory post-synaptic potentials (EPSPs) or IPSPs in the target neuron, the disturbance in the membrane potential of the target neuron will fade away and return to baseline (Rastogi, 2006; Starr and McMilan, 2015). The HVLA thrust delivered during the C5/C6 SMT is a rapid short-lived propulsive thrust that can produce a force between about 220 N to 550 N with a duration of between about 200 ms to 420 ms (Herzog *et al.*, 1993). The C5/C6 SMT would have therefore activated the mechanoreceptors in the C5/C6 facet joint tissue transiently with subsequent transient facilitation of biceps muscle autogenic inhibition during the modified stretching. This finding suggests that spinal manipulation may cause transient Ib inhibition on the homonymous motor neuron pool, theoretically by causing transient facilitation of the facet joint Ib inhibitory di- or tri-synaptic spinal reflex arc(s) via interpolation with Ib internuncials.

The Ib internuncials found in Rexed lamina VI and VII in the intermediate grey matter of the spinal cord were initially defined by their response to input from the GTOs. The more recent literature shows that a range of sensory input, including A β -fiber afferents from mechanoreceptors in joint tissue, can reach the Ib internuncials through several independent spinal reflex arcs and that there is little specialization of Ib internuncial by the type of sensory input (Brushart, 2011; Greger and Windhorst, 2013). Studies have substantiated that joint A β -fiber afferents can cause similar Ib inhibition on the homonymous α motor neurons (Brushart, 2011; Greger and Windhorst, 2013).

A current accepted neurophysiological mechanism underlying both spinal manipulation (DePalma, 2011; Sterling and Kenardy, 2011) and AMI in the literature entails affecting the afferent discharge of somatic receptors (type I-IV nerve endings / mechanoreceptors and nociceptors) found in joint tissues (Rice *et al.*, 2014; Rice and McNair, 2010). Spinal manipulation can stimulate and cause a transient increase in A β -fiber afferent discharge (Millan *et al.*, 2012; Pickar, 2002) of type I Ruffini end-organs around the collagen fibers of the superficial layers of the facet capsular tissue (slowly adapting,

low-threshold, static and dynamic mechanoreceptors); type II Pacinian corpuscles in the deeper layers of the facet capsular tissue (rapid adapting, low threshold and dynamic mechanoreceptors); and type III Golgi ending nerve endings at the junction between the inner and more superficial layers of the facet joint capsular ligament (very slowly adapting, high threshold and dynamic mechanoreceptors), their existence having been vindicated in many studies (McPetty, 2011; Sterling and Kenardy, 2011). Studies have affirmed that type I-III nerve endings in the facet joint tissue respond to the impulse of a HVLA load applied during SMT and not to loads with a slower force-time profile (Colloca *et al.*, 2000).

An increase in joint mechanoreceptor A β -fiber afferent discharge is strongly associated with AMI and it is postulated that joint afferent input has competing excitatory and inhibitory influences on the homonymous motor neuron pool; in a dysfunctional joint, the net effect can be inhibitory (Konishi *et al.*, 2003; Rice and McNair, 2010). The arthrokinetic spinal reflex arcs, in which somatic receptors in the joint tissue affect the spinal segmental innervated muscle activity, is dependent on the type of receptor activated. Activation of joint mechanoreceptors can, in addition to affecting the spinal segmental innervated muscles directly by affecting the homonymous α motor neuron's excitability, also affect the muscles by affecting the homonymous γ motor neuron-muscle spindle loop (Petty, 2011). Any joint dysfunction which can affect its mechanoreceptor A β -fiber afferent discharge can cause impairment of its arthrokinetic reflex functioning and produce abnormal patterns of spinal reflex arc activity (Middleditch and Oliver, 2005) and thereby result in weakness of the spinal segmental innervated muscles (Middleditch and Oliver, 2005; Porter, 2013), namely AMI (Rice *et al.*, 2014; Rice and McNair, 2010). Furthermore, a weak correlation exists between pain and AMI; several studies have affirmed the presence of significant AMI in the absence of pain. As little as 10 ml of fluid infused into joints can cause notable muscle inhibition, and even small, clinically undetectable joint effusions can cause significant AMI (Hopkins, 2006; Hopkins *et al.*, 2001; Rice *et al.*, 2014; Rice and McNair, 2010).

The finding of SMT facilitating Ib inhibition on the homonymous motor neuron pool suggests that by applying SMT over time to facet joints with raised A β -fiber afferent discharge and thus altered arthrokinetic reflex functioning, may desensitize the vertebral segment's facilitated facet joint Ib inhibitory spinal pathways by causing Ib inhibition on the homonymous lower motor neurons that is already subjected to AMI, with subsequent improved α -motor neuron functioning. By gradually or repeatedly inducing an abnormal stimuli or abnormal response over time, habituation can be achieved and result in a reduction of the abnormal stimuli or abnormal response (Lundy-Ekman, 2013; Sweetow and Sabes, 2010). Du Plessis (2014) investigated the effect of C5/C6 SMT on the EMG and strength of the biceps muscle in participants with chronic neck pain over a three week

period. Three measurements were recorded spanning the three weeks. The mean dynamometry increased from the first reading recorded as 20.67 kg to the second reading recorded as 21.49 kg, and increased from the second to the third reading recorded as 22.99 kg, with a significant increase in the biceps muscle strength over the three weeks ($p = 0.005$). The mean EMG amplitude increased from the first reading recorded as 150.76 mV to the second reading recorded as 151.66 mV, and increased from the second to the third reading recorded as 152.02 mV, with a significant increase in the biceps muscle activity over the three weeks ($p = 0.000$). Du Plessis (2014) concluded that the underlying neural mechanism responsible for the significant increase in the muscle force and activity post the SMT is unclear. The incremental increase in muscle force and activity over the three week period is possibly due to the SMT desensitizing altered arthrokinetic spinal reflex arcs present in the mean subject.

The theory of SMT causing transient Ib inhibition on the homonymous motor neuron pool is substantiated by many studies that observed an EMG response latency, a transient decrease in EMG amplitude, as well as the transient decrease in excitability of the homonymous motor neuron pool immediately post-SMT. Herzog *et al.* (1999) investigated the effect of SMT applied to the cervical, thoracic and lumbar spine and sacroiliac regions on the muscle activity of their associated paraspinal musculature in asymptomatic participants. They reported an EMG response latency occurring within 50 ms to 200 ms immediately after the HVLA thrust. Colloca and Keller (2001) confirmed these latter findings in symptomatic patients with low back pain. They reported an EMG response latency occurring within 2 ms to 3 ms immediately after AAI SMT. Dishman *et al.* (2002) investigated the immediate pre- and post-SMT effects of lumbar SMT on the homonymous motor neuron pool excitability in participants with low back pain, by measuring and recording the amplitude of the tibial nerve H-reflex recorded from the gastrocnemius muscle. They found a significant transient decrease in the homonymous motor neuron pool excitability immediately post the SMT.

The notion of SMT causing transient disinhibition of the homonymous α motor neurons are plausible (Dunning and Rushton, 2009; Olsen, 2015), but solely after the SMT has caused transient Ib inhibition on the homonymous motor neuron pool. Numerous studies have showed a transient increase in EMG (spike) following the EMG response latency immediately post-SMT (Olsen, 2015; DeVocht *et al.*, 2005; Pickar, 2002; Colloca and Keller, 2001; Herzog *et al.*, 1999), as well as an increase in muscle strength and / or decrease in AMI immediately post-SMT (Dunning and Rushton, 2009; Pickar, 2002; Suter and McMorland, 2002; Suter *et al.*, 2000).

The transient increase in EMG following the EMG response latency may be due to the SMT mechanically reducing a chiropractic subluxation complex present (Olsen, 2015; Pickar, 2002), and thereby causing disinhibition of the

altered arthrokinetic spinal reflex arcs. Repetitive postural strain or trauma to the spine can cause alterations in the normal anatomical, physiological and / or biomechanical dynamics of individual vertebral segments and produce relatively large vertebral motions that achieve a new position of stable equilibrium. The higher energy level needed to achieve the new position of stable equilibrium can place additional mechanical stress or overload on the facet joint capsular tissue and / or cause uneven or increased unilateral facet joint loading. These alterations in the vertebral segment can cause tension, pressure, stretching or irritation of the facet joint capsular tissue as well as the displacement of collagen in the facet joint capsular ligament (Gatterman, 2005; Vernon, 2010), and thereby stimulate (depolarize and sensitize) mechanoreceptors within the facet joint tissue and subsequently increase their A β -fiber afferent discharge frequency (Dunning and Rushton, 2009; Vernon, 2010), in the presence and absence of pain (Rice *et al.*, 2014; Rice and McNair, 2010). Raised A β -fiber afferent discharge from facet joint tissue caused by a chiropractic subluxation complex can theoretically cause alterations in its arthrokinetic reflex functioning with subsequent facilitation of the vertebral segment's facet joint's Ib inhibitory spinal reflex arcs and thereby AMI.

Prior to suggesting that the C5/C6 SMT facilitated biceps muscle GTO Ib afferent activity as part of the convergent input on the homonymous motor neuron pool excitability, it is vital to explore and consider other causes or contributors to the decrease in biceps muscle EMG RMS during the increase in biceps muscle force immediately post the C5/C6 SMT. Although several contributors may exist, the most relevant will be emphasised in this article.

Although all subjects in the this study were asymptomatic, nociceptors in the cutaneous and facet joint tissue may have also been stimulated due to the propulsive HVLA thrust applied during the SMT intervention (Millan *et al.*, 2012; Pickar, 2002). It is unlikely though that an increase in nociceptors A δ - and / or C-fiber afferent discharge caused or contributed to the decrease in biceps muscle EMG RMS immediately post the C5/C6 SMT, because the literature has shown that activated nociceptors afferent from joint and cutaneoustissue are more likely to cause an excitatory influence on the homonymous motor neuron pool excitability to result in or contribute to the induction of a muscle spasm (Mense and Gerwin, 2010; Steward, 2012). An excitatory influence on the homonymous motor neuron pool may contribute to an increase in the EMG RMS of the homonymous muscle during voluntary muscle contraction by causing disinhibition of the homonymous α motor neurons (Fitzgerald *et al.*, 2012; Merletti and Parker, 2004). Facilitation of an increased state of firing of the homonymous α motor neurons will not cause an increase in muscle strength (Mense and Gerwin, 2010), but may cause a decrease in muscle strength during voluntary muscle contraction if the muscle spasm is severe enough (Page *et al.*, 2010). The facilitation of increased excitability of

the homonymous motor neuron pool can cause alterations in the motor unit recruitment, lower the homonymous α motor neurons activation threshold, or lower their irritability threshold (Page *et al.*, 2010).

In addition, many studies have established that the input of $A\beta$ -fiber afferents of mechanoreceptors is more powerful than the input of $A\delta$ - and / or C-fiber afferents of nociceptors into the central nervous system (Haines, 2012; Steward, 2012). Many studies have shown that SMT stimulates and causes an increase of $A\beta$ -fiber afferent discharge of mechanoreceptors in facet joint tissue (DePalma, 2011; Millan *et al.*, 2012). Also, the literature has established that branches of large $A\beta$ -fibers afferent from joint tissues have shared innervation with the homonymous wide dynamic range neurons in the dorsal horn of the spinal cord that enter the posterior column-medial lemniscal pathway in the white matter of the spinal cord (Haines, 2012; Steward, 2012). Stimulation of the posterior column by way of the joint $A\beta$ -fibers afferent sends antidromic conducted action potentials via collateral branches into the dorsal horn which in turn stimulate the enkephalinergic interneurons that inhibit the transmission of nociceptive signals of the $A\delta$ - and / or C-fibers via the anterolateral system. This is the physiological basis for the gate theory of pain (Haines, 2012; Steward, 2012). Further, none of the participants of this study reported experiencing pain during the SMT intervention.

The activation of mechanoreceptors in the cutaneous tissue can exert an excitatory or inhibitory influence on the homonymous motor neuron pool excitability (Mense and Gerwin, 2010; Steward, 2012). However, it is unlikely that stimulation of mechanoreceptors in the cutaneous tissue by the C5/C6 SMT (Millan *et al.*, 2012; Pickar, 2002) solely caused the decrease in biceps muscle EMG RMS but may have served as a contributor. The placebo SMT may have also stimulated mechanoreceptors in the cutaneous tissue at the C5/C6 segment due to the contact of the AAI with the skin (Huggins *et al.*, 2012; Humphries *et al.*, 2013), but showed a much smaller decrease in the biceps muscle EMG RMS compared to the post-C5/C6 SMT, a difference of more than 7.16 %.

It is unlikely that the normal physiological functioning of the elbow joint arthrokinetic reflex activity caused the decrease in biceps muscle EMG RMS immediately post the C5/C6 SMT. When a joint capsule is stretched during joint movement the joint mechanoreceptors will cause activation of the muscles which will reduce the joint capsular stretch and cause inhibition of the muscles which will increase the joint capsular stretch (Middleditch and Oliver, 2005; Petty, 2011). During the modified stretching of the biceps muscle in this study; the mechanoreceptors in the elbow joint tissue would have exerted powerful tonic excitatory influences on the α motor neurons innervating the elbow flexor muscles with subsequent contribution to an increase in biceps muscle EMG RMS, and exerted inhibitory influences on the α motor neurons innervating the elbow extensor muscles, to reduce

the capsular stretch of the extended elbow joint (FitzGerald *et al.*, 2012; Mense and Gerwin, 2010). To the contrary, the C5/C6 SMT facilitating effect on the biceps muscle autogenic inhibition during the modified stretching was theoretically larger than the spatial summation of excitation produced by the LCST and elbow joint arthrokinetic reflex activity as part of the convergent input on the homonymous motor neuron pool excitability.

There are several limitations to this current study that need to be acknowledged. No verifications may exist to ensure that the desired spinal levels of manipulation will be indeed the specific C5/C6 level (Dunning and Rushton, 2009). By contrast, specific palpation of the vertebral bodies can lead to correct spinal level identification (Benzel, 2012; Magee, 2008). Although the same person (the researcher) applied the C5/C6 SMT to all participants, the magnitude of the thrusting force of the SMT applied cannot be standardized between all of the subjects. The exact replication of EMG electrode placement between all participants cannot be standardized and verified (Dunning and Rushton, 2009: 502). The exact replication of a low force isometric contraction of the biceps muscle during the modified stretching between all the subjects cannot be standardized due to voluntary effort (Lundy-Ekman, 2013; Merletti and Parker, 2004).

CONCLUSION

A decrease in biceps muscle EMG RMS in the face of an increase in biceps muscle force immediately post-C5/C6 SMT during modified stretching of the biceps muscle based on the principles of the autogenic inhibition phase of PNF stretching suggests that the C5/C6 SMT facilitated biceps muscle GTO autogenic inhibition as part of the convergent input on homonymous motor neuron pool excitability. This phenomenon has not been reported in the literature, due to EMG studies having investigated the effects of SMT on muscle activity pre- and post-maximum voluntary muscle contraction and not the effect of SMT on muscle activity during facilitated GTO Ib afferent activity which is what is required to produce the spatial summation of sufficient IPSPs in the homonymous α motor neurons to drive the membrane potential at the axon hillock of each depolarized homonymous α motor neuron away from firing threshold in order to prevent the LCST from transiently generating sequential action potentials in the homonymous α motor neurons. Also, the LCST (voluntary effort) has a stronger input on the lower motor neurons than Ib inhibition and thereby masked the Ib inhibitory effect of the SMT in these EMG studies. The theory of SMT causing transient Ib inhibition on the homonymous motor neuron pool is substantiated throughout the literature that showed an EMG response latency, a transient decrease in the EMG and decrease in excitability of the homonymous motor neuron pool immediately post-SMT (Colloca and Keller, 2001; DeVocht *et al.*, 2005; Dunning and Rushton, 2009; Dishman *et al.*, 2002; Herzog *et al.*, 1999; Pickar, 2002; Suter and McMorland, 2002; Olsen, 2015).

Further research is warranted to add statistical significance to this finding in order to substantiate the suggestion that for optimal management of the symptomatic and asymptomatic patient with muscle weakness suspected to be of arthrogenic nature, the application of SMT to the segmentally innervated facet joints may be a beneficial approach before traditional strength rehabilitation or training is initiated. SMT may desensitize altered arthrokinetic spinal reflex activity present with subsequent improved α -motor neuron functioning.

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The Reliability of the Axial Rotation Measuring Device in Measuring Thoracic Spine Rotation Range of Motion

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ABSTRACT

Aim: Due to limited studies pertaining to the thoracic spine, there appears to be no consensus regarding a gold standard to measure thoracic spine rotation range of motion. The axial rotation measuring device was first mentioned in a research report by Lenehan, Fryer and McLaughlin in 2003. The axial rotation measuring device was designed to test thoracic spine rotation range of motion in a seated position. A pilot study of eighteen participants was conducted in order to test the reliability of the device; despite this study little has been done to further establish the reliability and validity of the axial rotation measuring device.

The aim of this study was to determine the intra-examiner, test re-test reliability of the axial rotation measuring device, and to determine the measurement of agreement between the axial rotation measuring device and the bubble inclinometer and goniometer devices. In addition, to determine which of the devices is most reliable in measuring thoracic spine rotation range of motion.

Method: A total of fifty participants, aged between eighteen and forty-five, volunteered to be part of this study. Participants were required to have their range of motion measured over two consecutive days. Each participant had their thoracic rotation range of motion measured using the axial rotation measuring device, the goniometer and the bubble inclinometer. Each device required the participants to rotate their thoracic spine thrice towards the left and thrice towards the right, on both days of testing.

Results: The axial rotation measuring device demonstrated significant intra-examiner and test re-test reliability. However, poor agreement was seen between the axial rotation measuring device and the goniometer, and the axial rotation measuring device and the bubble inclinometer. Furthermore, the results showed the goniometer and inclinometer to demonstrate substantial intra-examiner and test re-test reliability, and a significant agreement between the two devices was determined.

Conclusion: The goniometer was determined to be the most reliable device when measuring thoracic spine rotation range of motion, due to the significant relative reliability and absolute reliability established. This was followed by the inclinometer, due to the significant relative reliability and moderate absolute reliability established. Further research should be done into determining the absolute reliability of the ARMD. Thus based on the results yielded by this study the ARMD should not be used as an alternative to the goniometer or inclinometer when measuring thoracic spine rotation range of motion.

INTRODUCTION

Clinical measurements of spinal range of motion are an integral part in patient evaluation and examination, with a fundamental role in physical therapy and rehabilitation. Objective measurements of range of motion can have a substantial effect on determining necessary therapeutic interventions (Gajdosik and Bohannon, 1988). The cervical and lumbar spines are the most common spinal regions studied, due to the notable injuries and conditions associated with them (Briggs, Smith, Straker and Bragge, 2009; Briggs, Bragge, Smith, Govil and Straker, 2009). In comparison the thoracic spine has been studied to a lesser extent in terms of clinical and epidemiological studies. This may be due to the difficulties associated in analysing movements of the thoracic spine region and the perpetuated belief that the

thoracic spine is less implicated in clinical pain syndromes (Edmondston and Singer, 1997). As a result of limited studies there is currently no consensus regarding a gold standard to measure thoracic spine rotation range of motion (Johnson and Grindstaff, 2010).

The axial rotation measuring device (ARMD) was first mentioned in a research report by Lenehan, Fryer, and McLaughlin (2003). The ARMD was designed to test thoracic spine rotation range of motion in a seated position. A pilot study was conducted in order to establish the reliability of the ARMD, and despite this pilot study, little has been done to further establish the reliability and validity of the ARMD (Lenehan, Fryer and McLaughlin, 2003).

The aim of this study was to determine the intra-examiner, test re-test reliability of the ARMD, and to determine the

measurement of agreement between the ARMD and the goniometer, and the ARMD and the bubble inclinometer. In addition, to determine which of these devices were most reliable in measuring thoracic spine rotation range of motion.

Quantifying a patient's range of motion can be extremely valuable in determining therapeutic interventions and monitoring treatment effectiveness. Unlike the lumbar and cervical spine regions, the thoracic spine has been the least studied spinal region. There is currently no gold standard method to measure thoracic spine rotation range of motion (Johnson and Grindstaff, 2010). Therefore, this study may be beneficial in providing a reliable and cost effective tool to determine thoracic spine rotation range of motion in a clinical setting.

METHODOLOGY

Design

This study design is a reliability study to determine the reliability of the ARMD, and to determine its measurement of agreement against the goniometer and bubble inclinometer.

Participants

A selection of 50 participants was recruited for this study. The participants were made up of males and females between the ages of 18 and 45 years old. Participants recruited were asked to read an information form and sign a consent form specific to this study, confirming that they fully understand all the procedures involved in this study

Participants were recruited by means of advertisements placed around the University of Johannesburg, Doornfontein campus, local shopping malls and gymnasiums. Participants were also recruited by word of mouth around the University of Johannesburg, Doornfontein campus. Participants were accepted based on an inclusion and exclusion criteria. This study was approved by the Faculty of Health Sciences Research Ethics Committee (clearance number REC 01-158-2016).

Procedures

All 50 participants were seen over two consecutive days at the University of Johannesburg, Chiropractic Clinic in Doornfontein. Upon arrival, an explanation was given on how the study was performed and what was required from the participants. The reading of the information form and signing of the consent form was then completed. A thorough case history, physical examination, cervical spine regional and lumbar spine regional exams were performed on each individual.

The participant's thoracic rotation range of motion was subsequently measured using the ARMD, followed by the goniometer and lastly the bubble inclinometer. A strict patient setup for each of the three measuring instruments was followed in order to standardize testing. The examination began with the ARMD. The participant was placed in a seated

position on a sturdy, height adjustable stool to maintain 90 degrees of hip and knee flexion in the seated position. The participant was asked to rotate the trunk to the left as far as they were able to go. This was repeated 3 times towards the same direction. There was a 10 second latent period between each rotation. The degree of each rotation was then recorded in the patients file. The participant was thereafter asked to rotate towards the right three times and the same procedure followed. After 10 minutes the same participant was setup for the Seated Rotation Test using the goniometer according to a specific patient set up and the same procedure followed. After another ten minutes the patient was setup for the Lumbar-locked Rotation Test using the bubble inclinometer according to a specific patient setup and the same procedure followed. All testing was conducted by the same examiner over two consecutive days.

The second visit occurred on the day immediately after the first visit, a minimum of 24 hours later, however no later than 48 hours. The exact same protocols and patient setups from the first visit were maintained throughout the second visit.

The seated rotation test using the goniometer

All participants were asked to be seated, with hips and knees flexed to 90 degrees; a ball was then placed between the knees to minimize motion of the lower extremities during thoracic spine rotation. The ball was held in place by light adduction of the participant's thighs. A standard lightweight bar, with a piece of tape marking the midpoint, was used to standardize the position of the upper extremity. The bar was placed across the chest and the arms were crossed over it (Johnson *et al.*, 2012).

The goniometer was then aligned parallel to the ground at the midpoint between the T1 and T2 spinous processes, with the spine of the scapula as a reference point. The stationary arm pointed away from the rotating side and remained parallel to the starting position. The participant was instructed to continue looking forward at an eye-level mark on the wall while maximally rotating to the left. The examiner followed this motion with the moving arm of the goniometer. Once the participant reached end range of motion, the angle of the goniometer was noted and the degree of rotation was recorded in the participants file. Each measurement was obtained three times on both the right and left sides with a latent period of 10 seconds between each rotation (Johnson *et al.*, 2012).

The lumbar-locked rotation test using the inclinometer

All participants were positioned kneeling on a towel, maintaining upper extremity support with the elbows and forearms placed on the floor. This position places the hips and lumbar spine into maximal flexion, reducing the contributions of the pelvis and lumbar spine during thoracic rotation. The bubble inclinometer was positioned between the scapular spines at the T1-T2 level. Rotation was

performed with the participant placing the ipsilateral hand on the posterior aspect of the neck and rotating the thoracic spine while maintaining the kneeling position (Johnson *et al.*, 2012). Once the participant reached end range of motion, the angle of the bubble inclinometer was maintained, and the examiner read and recorded the measurement. Each measurement was obtained 3 times on rotation towards the right and left sides with a latent period of 10 seconds between each rotation (Johnson *et al.*, 2012).

The axial rotation measuring device

Each participant was asked to sit on a sturdy, height adjustable stool in front of the ARMD. The stool height was adjusted to ensure that the scapula beam was in level with the interscapular line. Participants were then instructed to place their arms behind them over the scapula beam. The pelvis of each participant was stabilised by the examiner. The participant was instructed to continue looking forward at an eye-level mark on the wall while maximally rotating their torso to the left. Once the participant reached end range of motion, the degree of rotation was read and recorded by the examiner. The participant was then asked to return to the neutral position for a latent period of ten seconds before the procedure was repeated towards the same side. Each participant completed bilateral rotations three times towards each side (Lenehan, Fryer and McLaughlin, 2003). All measurements were recorded in the participants file.

Statistical analysis

The mean values for thoracic rotation range of motion using the goniometer device, the bubble inclinometer device and the ARMD was computed using descriptive statistics. Intra-class correlation coefficients (ICC) and 95% confidence intervals (CI) were used to determine the correlation for right hand side (RHS) rotation and left hand side (LHS) rotation between sessions one and two, for the ARMD, the goniometer and the bubble inclinometer, respectively. Therefore, determining the intra-rater, test re-test reliability for each of the three devices.

Bland-Altman plots were also utilized to analyze the bias and 95% limits of agreement (LOA) for each of the three devices. One-way repeated measures analysis of variance (ANOVA) was utilized to determine the statistical significance between all three devices. The value of significance, the *p*-value, was set at 0.05 for all tests. If the *p*-value was less than or equal to 0.05 ($p \leq 0.05$), there was a statistically significant difference between the three measuring devices. If the *p*-value was greater than 0.05 ($p > 0.05$), no statistical significant difference existed between the measuring devices.

In addition, standard error of measurement (SEM) was computed using the formula $SEM = SD \times \sqrt{1 - ICC}$, where SD represents the standard deviation and ICC is the reliability coefficient for the respective measuring device used. Furthermore the minimal detectable change (MDC) was computed using the formula $MDC = SEM \times 1.96 \times \sqrt{2}$. Standard

error of measurement was calculated to determine the measurement error associated with each measuring device in order to provide an absolute index of reliability. Minimal detectable change was utilized to detect the minimum amount of change produced by each device that was not the result of the associated measurement error.

RESULTS

Intra-class correlation coefficients

Table 1: Table depicting the between day ICC and 95% CI values

Instrument	LHS		RHS	
	ICC	95% CI	ICC	95% CI
ARMD	0.94	0.89-0.96	0.80	0.66-0.89
Goniometer	0.96	0.92-0.97	0.95	0.91-0.97
Inclinometer	0.91	0.85-0.95	0.89	0.80-0.94

According to [table 1](#), ICC values were above 0.90 for all three measuring devices. As a general observation the, ICC's were quite similar for all three measuring devices.

The ARMD had an ICC value of 0.94 for LHS rotation and 0.80 for RHS rotation thus indicating a strong correlation between the measurements from days one and two. The ARMD's lower-bound CI of 0.66-0.89 for RHS rotation was the lowest and widest recorded.

The goniometer revealed to have an ICC value of 0.96 for LHS rotation and 0.95 for RHS rotation, thus indicating a strong correlation between the measurements from days one and two. These were the highest ICC values amongst all three devices.

The inclinometer had an ICC of 0.91 for LHS rotation and 0.89 for RHS rotation thus indicating a strong correlation between the measurements from days one and two

As all ICC values were above 0.90 a significant correlation was demonstrated between day's one and two for each of the three devices.

Bland-Altman analysis

Table 2: Table depicting the bias and upper and lower limits of agreement for each device

Instrument	LHS			RHS		
	Bias°	Lower LOA°	Upper LOA°	Bias°	Lower LOA°	Upper LOA°
ARMD	-0.5	-5.41	5.41	-0.9	-11.15	4.14
Goniometer	-0.2	-3.89	3.17	-0.9	-6.29	2.33
Inclinometer	-0.8	-6.6	2.8	-0.5	-8.12	4.82

As indicated in [table 2](#), all measuring devices have shown low bias with a mean average difference ranging from -0.2° to -0.9°.

The goniometer had the lowest mean average difference

Table 3: Table depicting the between days standard error of measurement and the minimal detectable change for each device

Instrument	LHS				RHS			
	SD	ICC	SEM°	MDC°	SD	ICC	SEM°	MDC°
ARMD	2.2	0.94	1.26	4.94	3.9	0.80	3.1	12.15
Goniometer	1.8	0.96	0.84	3.29	2.2	0.95	1.25	4.9
Inclinometer	2.4	0.91	1.49	5.84	3.3	0.89	2.41	9.45

of -0.2° , with the lowest 95% LOA ranging from -3.89° to 3.17° , for LHS rotation. The goniometer also had a low mean average difference of -0.9° , with a 95% LOA ranging from -6.29° to 2.33° , for RHS rotation.

The ARMD produced a low mean average difference of -0.5° and -0.9° for left and right hand side rotation, respectively. However, it had the widest overall variability between the lower and upper 95% LOA ranging at -5.41° to 5.41° for LHS rotation and -11.15° to 4.14° for RHS rotation.

The inclinometer also produced a low mean average difference of -0.8° and -0.5° for left and right hand side rotation respectively, with the second overall widest variability between the lower and upper 95% LOA ranging at -6.6° to 2.8° for LHS rotation and -8.12° to 4.82° for RHS rotation.

Standard error of measurement and minimal detectable change

As indicated in [table 3](#), the SEM ranged from 0.84° to 3.1° . The goniometer had the lowest SEM values for both LHS and RHS rotation, at 0.84° and 1.25° , respectively. The inclinometer had an SEM of 1.49° for LHS rotation and 2.41° for RHS rotation. The ARMD had and SEM of 1.26° for LHS rotation, and 3.1° for RHS rotation, thereby attributing the highest error variability to the ARMD for RHS rotation.

As indicated in [table 3](#), the MDC values ranged from 3.29° to 12.15° . The goniometer had the lowest MDC values at 3.29° for LHS rotation and 4.9° for RHS rotation. The inclinometer had an MDC of 5.84° for LHS rotation and 9.45° for RHS rotation. The ARMD had and MDC of 4.95° for LHS rotation, and 12.15° for RHS rotation. Thus, high MDC results were noted for the inclinometer and ARMD, specifically during RHS rotation.

Analysis of variance

Repeated measures ANOVA were computed in order to determine the agreement between the ARMD, the goniometer and the inclinometer over the two days. The p -value, was set at 0.05 for all tests. If the p -value was less than or equal to 0.05 ($p \leq 0.05$), there was a statistically significant difference between the three measuring devices. If the p -value was greater than 0.05 ($p > 0.05$), no statistical significant difference existed between the measuring devices.

The Wilks' Lambda test was chosen to determine if a change was found over the 24-48 hour time period, between

the ARMD the goniometer and the inclinometer. The p -value was 0.000 for LHS and RHS rotation, within session and between days one and two. Thus, indicating that a statistical difference in mean thoracic rotation range of motion existed between the three measuring devices.

Due to the statistical difference between the ARMD, the goniometer and the inclinometer, the magnitude of the difference was determined using the partial eta squared value. The partial eta squared value for overall LHS rotation was 0.42 and 0.29 for overall RHS rotation. According to the commonly used guidelines proposed by Cohen (1988): a value of 0.01 is small, a value of 0.06 is moderate, and a value of 0.14 is large. Therefore, the result attained was large. Due to there being a significant difference between the three measuring devices, pairwise comparisons were then done to determine between which devices the differences existed.

The p -values for the goniometer and the ARMD, and the inclinometer and the ARMD were both 0.000 (for LHS rotation). Due to the p -value being ≤ 0.05 , a statistical difference existed between the ARMD and the goniometer, and the ARMD and the inclinometer when measuring LHS rotation. The p -values for the goniometer and the inclinometer were 0.38. Due to the p -value being > 0.05 no significant difference existed between the goniometer and the inclinometer when measuring LHS rotation.

Pairwise comparisons for overall RHS rotation revealed a p -value less than 0.05 for the goniometer and the ARMD, and the inclinometer and the ARMD. Due to the p -value being ≤ 0.05 , a statistical difference existed between the ARMD and the goniometer, and the ARMD and the inclinometer when measuring RHS rotation. The p -values for the goniometer and the inclinometer were 0.45. Due to the p -value being > 0.05 no significant difference existed between the goniometer and the inclinometer when measuring RHS rotation.

DISCUSSION

The purpose of this research study was to determine the intra-examiner, test re-test reliability of the ARMD, and to determine the measurement of agreement between the ARMD and the goniometer and the inclinometer devices. In addition, to determine which of the devices was most reliable in measuring thoracic spine rotation range of motion.

When adhering to the procedures outlined in this research study, measurements taken using the goniometer by means

of the standardised method termed the Seated Rotation Test (Johnson and Grindstaff, 2010), showed significant test re-test reliability and good between-day agreements. These reliability results are comparable to previous research which had reported statistically significant ICC values when utilizing the same method procedure (Johnson *et al.*, 2012). Thus, relative reliability can be attributed to the goniometer.

With regards to the determination of agreement, measurements produced by the goniometer were found to be comparable to those taken with the inclinometer, as no statistical differences existed between these devices. This was further validated by Bland-Altman plots which showed strong agreements between the two devices. Furthermore, the SEM and MDC values for the goniometer were significantly low and similar to those reported in previous research (Johnson *et al.*, 2012). Therefore, absolute reliability can be attributed to the goniometer.

Measurements taken using the inclinometer by means of the standardized method termed the Lumbar-locked Rotation Test (Johnson and Grindstaff, 2010), showed significant test re-test reliability and significant between day agreements. These reliability results are comparable to previous research which had reported statistically significant ICC values when utilizing the same method procedure (Johnson *et al.*, 2012). Thus, relative reliability can be attributed to the inclinometer.

As mentioned above, the inclinometer showed a strong degree of agreement when compared to the goniometer. The SEM values for the inclinometer were evidently low as were the MDC value for LHS rotation, these finding correlated with previous research (Johnson *et al.*, 2012). However the MDC value (9.45°) for RHS rotation was moderate to high therefore limiting the sensitivity of the inclinometer to determine actual changes in thoracic rotation range of motion below this value, which is not susceptible to error. Thus, moderate absolute reliability can be attributed to the inclinometer.

In a clinical setting, the ability to reproduce measurements accurately is fundamental in assessing the effects of therapeutic techniques such as joint manipulation (Krause, Boyd, Hager, Smoyer, Thompson, and Hollman, 2015). It is therefore imperative for practitioners and researchers to have accurate and pertinent information regarding the reliability of tools used to measure range of motion (Muir, Corea, and Beaupre, 2010). Given the reliability results of this study, one can conclude that the goniometer and inclinometer shows to be significantly reliable when measuring thoracic rotation range of motion, however, awareness should be brought to the questionable sensitivity of the inclinometer at determining change that is not susceptible to error.

Measurements taken using the ARMD showed substantial test re-test reliability and average to good between-day agreements. These reliability results were comparable to the reliability pilot study conducted by Lenahan, Fryer and McLaughlin (2003). Although significant relative reliability

could be attributed to the ARMD, the findings of the aforementioned pilot study was limited to a sixty minute time period, thus findings from this research study could not be adequately compared to that of the pilot study. In addition, the agreement between the ARMD and other measuring devices was not established in the pilot study.

This study revealed overall poor to average agreement between the ARMD and the goniometer between days one and two. Poor agreement was determined for LHS rotation, and poor to average agreement was determined for RHS rotation. Similarly, this study has shown poor agreement between the ARMD and the inclinometer, for both right and left hand side thoracic rotation range of motion.

Overall the goniometer and inclinometer underestimated values when compared to the ARMD, however, given that the goniometer and inclinometer produced results that were not statistically different from each other, and that such results are corroborated by the reliability study by Johnson *et al.* (2012), one can infer that measurement error was associated with the ARMD. Thus, concluding that the ARMD is not absolutely reliable.

When comparing instruments it is important to consider limitations associated with each device, which may have contributed to systematic error. A limitation of goniometry is that it requires the examiner to use both hands and to identify anatomical landmarks, as a result no stability is provided to the pelvis. Furthermore, the examiner must have adequate knowledge of anatomical landmarks. This increases the risk of error by incorrect placement, or by contribution of pelvic motion during axial rotation (Kolber *et al.*, 2012).

The inclinometer uses a fixed vertical reference point that is realized by gravity, this reference point will remain stable provided it is accurately calibrated to zero before each reading. If such reference point is not calibrated to zero, incorrect measurement may occur (Kolber *et al.*, 2013). Limitations associated with the ARMD have not been established due to limited research, resulting in a number of factors which may have contributed to systematic error, such as design and procedure flaws.

CONCLUSIONS

In conclusion, evidence of the results obtained suggest that the ARMD is reliable when measuring thoracic spine rotation range of motion, as this was determined based on the significant relative reliability that was established. However, the ARMD was not determined to be absolutely reliable as this was due to the poor agreement between the ARMD and the goniometer, and so too the ARMD and the inclinometer, as well as due to the low sensitivity in detecting actual changes in thoracic rotation range of motion that is not susceptible to measurement error.

The goniometer was determined to be the most reliable device when measuring thoracic spine rotation range of motion, due to the significant relative reliability and absolute reliability established. This was followed by the inclinometer,

due to the significant relative reliability and moderate absolute reliability established.

Further research should be done into determining the absolute reliability of the ARMD. Thus based on the results yielded by this study the ARMD should not be used as an alternative to the goniometer or inclinometer when measuring thoracic spine rotation range of motion.

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The effect of sacroiliac joint manipulation on lumbar extensor muscle endurance in asymptomatic individuals

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ABSTRACT

Background: Spinal manipulation has been shown to alter paraspinal muscle mechanoreceptor afferent output, altering motor neuronal pool activity. Changes in maximum voluntary contraction of the paraspinal muscles have been found following SMT yet it is unclear if these changes affect paraspinal muscle endurance. This study aimed to determine the effect of sacroiliac joint (SIJ) manipulation on lumbar paraspinal muscle endurance time.

Method: A randomised, placebo-controlled pre-test post-test design was used to recruit 40 asymptomatic, male participants, allocated to one of two groups. The intervention consisted of SIJ manipulation or a sham. Lumbar spine range of motion, paraspinal muscle endurance time, length and muscle activity were measured. A $p < 0.05$ was considered significant. Analysis was done using IBM* SPSS Statistics version 21 and SATA11.

Results: SIJ manipulation resulted in a significant increase in lumbar paraspinal muscle endurance time compared to the placebo ($p = 0.004$). There was no significant difference between the groups for mean and peak muscle activity ($p > 0.05$), lumbar spine extension range of motion ($p = 0.876$) or paraspinal muscle length ($p = 0.539$).

Conclusions: SIJ manipulation resulted in increased paraspinal muscle endurance time when compared to a placebo intervention with both groups showing increased paraspinal muscle activity. Further research into changes of muscle function post-manipulation is necessary to confirm these results.

INTRODUCTION

Spinal manipulative therapy (SMT) is practiced by chiropractors and other manual therapists and has been shown to be effective in the conservative management of musculoskeletal disorders such as back and neck pain (Ferreira, Ferreira, Latimer, Herbert and Maher, 2003; Bronfort, Haas, Evans and Bouter, 2004; Potter, McCarthy and Oldham, 2005; Dagenais, Gay, Tricco, Freeman and Mayer, 2010; Goertz, Pohlman, Vining, Brantingham and Long, 2012). It is a manual treatment that is directed at restrictions in joint movement in order to restore joint range of motion and alignment. Joint fixations may result from segmental muscle spasm, joint and intradiscal derangements, intercapsular adhesions, soft-tissue fibrosis (Bergmann and Peterson, 2011) and psychological distress such as anxiety and depression (Musculino, 2011). They are often associated with pain and paraspinal muscle hypertonicity (Leach, 2004).

The exact mechanism underlying the effectiveness of SMT is poorly understood (Herzog et al, 1999; Colloca and Keller, 2001; Koppenhaver, Fritz, Hebert, Kawchuk, Childs, Parent, Gill and Teyhen, 2011). Literature discuss that the mechanical stimulus provided by SMT results in neurophysiological consequences (Pickar, 2002) that have peripheral, spinal and supraspinal effects (Bialosky,

Bishop, Price, Robinson and George, 2009). When a joint loses its range of motion persistent nociceptive and altered proprioceptive input may result in a segmental cord response, leading to the development of pathological somatosomatic and somatovisceral reflexes. If these reflexes persist, they may alter function in the segmentally supplied somatic or visceral structures (Bergmann and Peterson, 2011), resulting in pain, discomfort and altered muscle function (Pickar, 2002). When SMT is administered it stimulates tissue mechanoreceptors altering the inflow of sensory information to the central nervous system (Pickar, 2002) which changes reflex pathways and inhibits motor neuron pools leading to a reduction of muscle hypertonicity and pain (Katavich, 1998), and improves the functional ability of the muscles (Potter *et al.*, 2005). Pickar and Colleagues have shown that not only the impulse of SMT (Pickar and Wheeler, 2001; Pickar and Kang, 2006; Pickar, Sung, Kang and Ge, 2007; Cao, Reed, Long, Kawchuk and Pickar, 2013) result in mechanoreceptor firing but that the preloading also bring about an effect. This effect is not as great as that achieved by the impulse of SMT.

When assessing the effects of lumbosacral SMT and/or mobilisation on paraspinal muscle function, studies have found either a transient decrease in muscle activity (Devocht, Pickar and Wilder, 2005; Krekoukias, Petty and Cheek,

Table 1: Screening questions for volunteers screening

Questions asked of respondents

Would you be willing to answer a few questions in order to determine your eligibility into the study?
Are you currently healthy?
Are you male?
Are you between the ages of 20 and 40 years old?
Are you right handed?
Have you experienced any low back pain in the last three months?
Do you know your weight and height in order for me to calculate your body mass index (BMI)?
Have you had any major spinal traumas, spinal surgeries, or suffer from any chronic illnesses?

2009; Lalanne, Lanfond and Descarreaux, 2009) or alpha motor neuron inhibition (Murphy, Dawson and Slack, 1995; Dishman and Bulbulian, 2000; Dishman, Cunningham and Burke, 2002; Dishman and Burke, 2003; Dishman, Dougherty and Burke, 2005; Fryer and Pearce, 2012). Keller and Colloca (2000) reported significant increases in maximum voluntary contraction of the paraspinal muscles, at the same segmental level where instrument manipulation was administered post-treatment. Supporting that SMT caused a change in sensory input that may have resulted in altered efferent pathways at that segmental level.

Paraspinal muscles provide functional stability and control movement to the spine (Bogduk, 2005; Moore and Dalley, 2006), therefore sufficient endurance is important for the good health of the spine (Moffroid, 1997). Reduced trunk extensor endurance has been linked to mechanical low back pain (MLBP) in adults (Biering-Sorensen, 1984; Demoulin, Vanderthommen, Duysens and Crielaard, 2006) and adolescents (Bernard, Bard, Pujol, Combey, Boussard, Begue and Salghetti, 2008). This occurs due to the reduced ability of the paraspinal muscles to support the spine, which may lead to overloading of the soft tissue and passive structures of the lumbar spine (Wilder, Aleksiev, Magnusson, Pope, Spratt and Goel, 1996) resulting in pain. MLBP is one of the most common musculoskeletal conditions, with a lifetime prevalence of 60 to 85% (Krismer and van Tulder, 2007). It has thus become one of the most costly conditions to manage (Dagenais, Caro and Haldeman, 2008; Bell and Burnett, 2009). Therefore determining ways to improve trunk extensor muscle endurance has become a focus of research. Therefore understating how SMT affects muscle function is important to further understand how it brings about its therapeutic effects. Thus this study aims to determine if sacroiliac joint manipulation compared to placebo treatment of the sacroiliac joint affects lumbar extensor muscle endurance.

Research problem statement

The neurophysiological effects that occur following spinal manipulation are needed to be investigated in order to further understand how patients receiving SMT have the improved clinical outcomes observed by clinicians and reported in clinical trials. Paraspinal muscle function is altered in low

back pain sufferers. Studies show that SMT affects paraspinal muscle mechanoreceptor input to the spinal cord. Thus this study aims to determine if these changes result in improved paraspinal muscle function in terms of the paraspinal endurance muscle test.

Aim of the study

This study aimed to determine the effect of sacroiliac joint manipulation on lumbar extensor muscle endurance compared to a placebo intervention, in terms of primary (lumbar extensor muscle endurance time and paraspinal muscle activity) and secondary (lumbar spine range of motion and paraspinal muscle length) outcomes in asymptomatic individuals residing in the eThekweni municipality.

METHODOLOGY

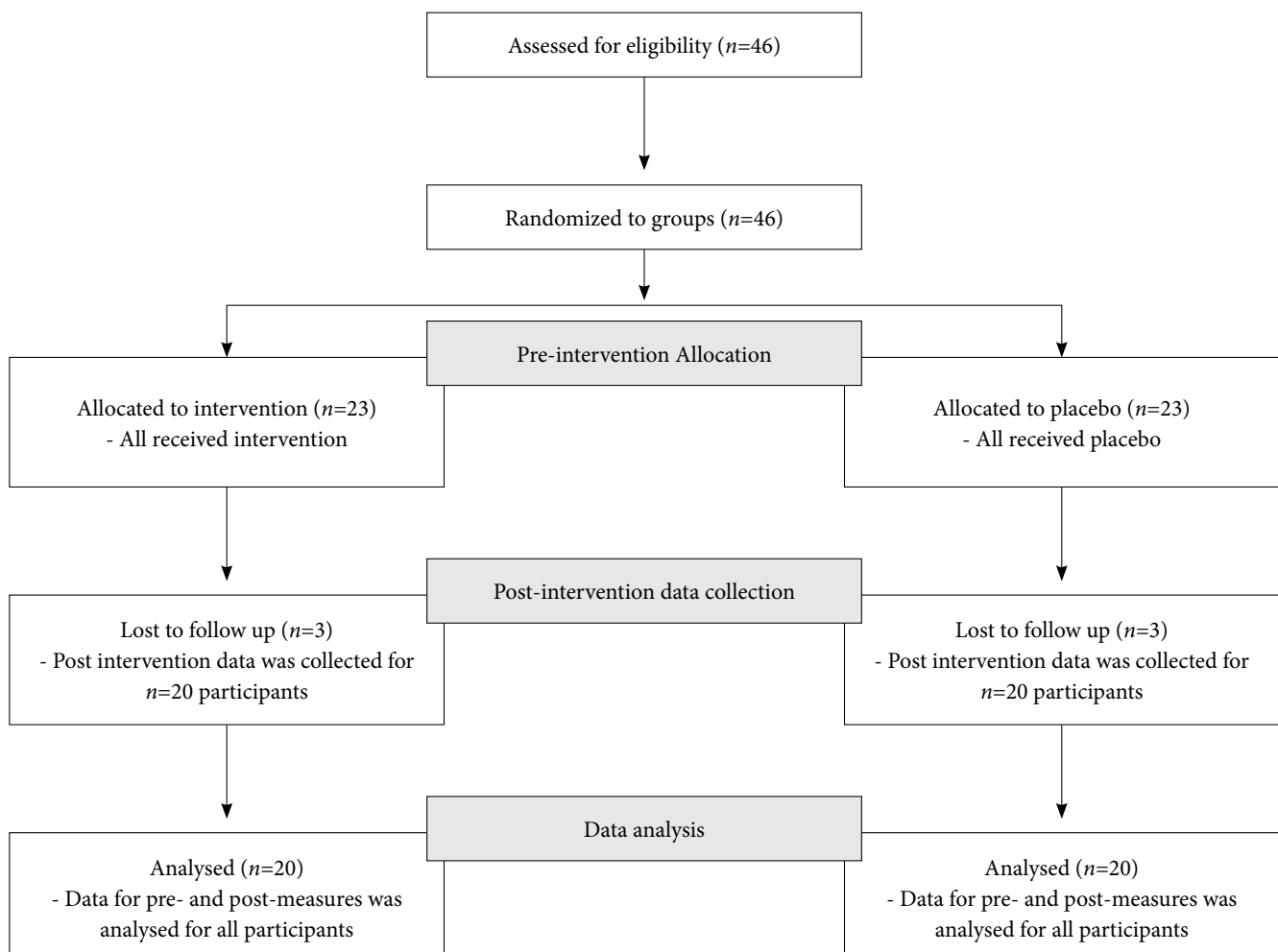
Study population

This double blinded, randomised, placebo-controlled pre-test post-test experimental study recruited 40 participants from the eThekweni municipality. The study was approved by the Institutional Research Ethics Committee of the Durban University of Technology (IREC 066/13) and was registered on the South African Clinical Trials register. Volunteers were informed about the study via adverts placed at University campus, places of gathering and through word of mouth. They contacted the researcher telephonically, where they were screened for eligibility by the questions in [Table 1](#). If eligible they were invited to an assessment at the Durban University of Technology Chiropractic Day Clinic where a case history, physical and orthopaedic examination was conducted after the volunteers gave written informed consent.

In order to partake the participants were required to meet the inclusion and exclusion criteria listed in [Table 2](#). The study was limited to males only as differences have been found between the genders with regards to performing the Biering-Sorensen paraspinal endurance test (Kankaanpää, Laaksonen, Taimela, Kokko, Airakinen and Hänninen, 1998; Mannion, Connolly, Wood and Dolan, 1997). For sample homogeneity the participants needed to be right hand dominant, have a body mass index (BMI) between 18.5 kg/m² and 24.9 kg/m² (normal) and be between the ages of 18 and 40 years of age.

Table 2: Study inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. Male sex	1. Holding the Beiring Sorensens extensor muscle endurance test for more than 176 seconds.
2. Aged between of 20 and 40 year of age	2. Low back pain within the last three months.
3. Right handed dominant	3. Medical conditions making physical activity unsafe for the participant (Champagne et al, 2009).
4. A body mass index between 18.5 kg/m ² and 24.9 kg/m ² .	4. Significant trauma affecting the low back, or if the clinical assessment warranted that the participant needed radiographic analysis.
5. A sacroiliac joint (SIJ) restriction determined by motion palpation, performed according to the techniques of Bergman and Peterson (2011)	5. Previous spinal surgery.
6. Hypertonicity of the paraspinal muscles, verified by the paraspinal muscle length assessment (Hammer, 2007).	6. On-going treatment for LBP by other health care providers.
	7. Any mechanical or manual intervention to the thoracic or lumbar spine three weeks prior to the study.
	8. The use of any muscle relaxants for any reason within 72 hours (three day) wash out period before commencement of the study (Seth, 1999).
	9. Contraindications to SIJ manipulation such as abdominal aortic aneurysm, tumour and osteomyelitis (Bergmann and Peterson, 2011; Gatterman, 1990).
	10. Contraindications to surface electromyography such as skin irritation, open wounds, or skin conditions affecting electrode placement

Figure 1: Flow of participants through study

This age group excluded those under 18 years negating the necessity for parental consent and reduced the likelihood of including those who may have spinal degenerative changes (Beers, Porter, Jones, Kaplan and Berkwits, 2006). Participants were required to have at least one sacroiliac joint (SIJ) restriction determined by motion palpation, performed according to the techniques of Bergman and Peterson (2011), which was verified by the research assistant. Plus they needed to have paraspinal muscle hypertonicity which was assessed by the paraspinal muscle length assessment (Hammer, 2007). Participants were excluded if they were competent in executing the Biering-Sorensen's test i.e. they could maintain the test position for greater than 176 seconds or if they had a medical condition making physical activity unsafe (Champagne, Descarreaux and Lafond, 2009). Other reasons for exclusion were: significant low back trauma, the necessity for radiographic analysis, previous spinal surgery, low back pain in the preceding three months or on-going treatment for LBP, any mechanical or manual intervention to the thoracic or lumbar spine three weeks prior to the study. If the participant had taken muscle relaxants for any reason within 72 hours a wash out period was allowed before they could be enrolled (Seth, 1999). If the participant presented with any contraindications to SIJ manipulation, such as osteoporosis and fracture (Bergmann and Peterson, 2011; Gatterman, 1990), or surface electromyography, like open wounds and psoriasis, they were excluded.

Six participants were excluded as while performing the Biering-Sorensen extensor endurance test one participant experienced calf cramp, one participant experienced pain in their foot due to the ankle strap, and four participants lost concentration and their results could not be used, they were replaced.

Procedure

Once meeting the study inclusion criteria the participant was randomly allocated, by a research assistant, using a computer generated random allocation chart, which was provided by the statistician, into one of two groups. Group one received SIJ manipulation, the intervention, while group two received the placebo. Prior to receiving the respective interventions the baseline measurements were taken. The prone abdominal draw in test, as described by Richardson, Jull, Hodges, and Hides (1999) was utilised to measure transversus abdominus muscle contractibility. A drop of 6-10 mmHg was considered normal and recorded as 'good', whereas if the participant was able to perform the test properly it was recorded as 'poor'.

Active lumbar spine range of motion, only flexion and extension, was assessed using the Saunders Digital Inclinator according to the technique outlined in the Saunders Digital Inclinator User's Guide (1998). Participants stood on a flat, firm surface, the measures were recorded from a neutral position to their limit of motion. Three repetitions were performed, recorded and the average score was used for data analysis. The participant were taught

how to perform the Biering-Sorensen paraspinal endurance test, according to the procedure outlined by Demoulin *et al.* (2006). The participant lay prone on an examination table with the upper edge of the iliac crests aligned with the edge of the table, in order that their trunk extended beyond the edge of the examination table. Their lower body was strapped to the table securing their pelvis, knees and ankles. They were instructed to fold their arms across their chest and rested on their trunk on a chair maintaining neutral position while not performing the test. At the start of the test the support was removed and the patient was required to maintain the horizontal position of their trunk parallel with the floor, with their head in a neutral position by looking down at a visual point on the floor. A tactile feedback was utilised by placing a rope hung between two vertical stands, placed perpendicular to the T7 vertebra (Coorevits, Daneels, Cambier, Ramon, Druyts, Karlsson, De Moor and Vanderstraeten, 2008a; Coorevits, Daneels, Cambier, Ramon and Vanderstraeten, 2008b; Koumantakis, Arnall, Cooper and Oldham, 2001) was used to improve the accuracy of the test. The endurance time, in seconds, was recorded from when the support was removed to when the participant could no longer hold the horizontal position, and the contact between the T7 vertebra and the rope was lost.

Prior to taking the Biering-Sorensen test measures the skin where the surface electrodes were to be placed was cleaned with alcohol, and when necessary hairy skin was shaved using a disposable razor (Neuro Trac™ ETS: Operators manual, 2007; DeVocht, Pickar and Wilder, 2005; Bicalho, Settii, Macagnan, Cano and Manffra, 2010). Each participant had their seventh and tenth thoracic vertebrae (T7 and T10) and third lumbar vertebrae (L3) marked using a water soluble marker with an 'X' over the spinous process (DeVocht Pickar and Wilder, 2005). Pairs of electrodes were placed bilaterally at the level of T10 and L3 (Dolan and Adams, 1993; Dolan and Adams, 1998; Mannion *et al.*, 1997) with an inter-electrode distance of approximately 3.5cm (Krekoukias, Petty and Cheek, 2009) in the midline of the muscle belly (De Luca, 1997). The Neuro Trac™ ETS unit (Verity Medical LTD, Uplands Place, Drove Road, Chilbolton, England, ISO9001:2000, MDD93/42/EEC) was utilised to obtain the data using the training template in EMG mode, which was set for 5 minutes, and recorded the endurance time, and the mean microvolts (mVs) (Neuro Trac™ ETS: Operators manual, 2007). Self-adhesive hypo-allergenic surface electrodes (VS.30 30 mm diameter round) were used (Neuro Trac™ ETS: Operators manual, 2007). The EMG Threshold Level was then set by asking the participant to perform the B-S test, hold the position for approximately 5 seconds, then relax for 5 to 10 seconds before repeating the same extensor muscle contraction. The average of the two peak readings was calculated and 40% of this reading was used as the threshold level. The EMG parameters of a narrow filter was used to eliminate interference from the heart (Neuro Trac™ ETS: Operators manual, 2007).

Table 3: Height (m), weight (kg) and body mass index (BMI) (kg/m²) per group

Category	Group	N	Mean (±SD)	CI	p Value
Height (m)	Intervention	20	1.78 (0.05)	1.75 - 1.81	0.709
	Placebo	20	1.77 (0.06)	1.74 - 1.80	
Weight (kg)	Intervention	20	72.77 (9.33)	68.51 - 76.99	0.725
	Placebo	20	73.78 (8.58)	69.89 - 77.66	
BMI (kg/m ²)	Intervention	20	22.78 (2.36)	21.72 - 23.85	0.466
	Placebo	20	23.27 (1.80)	22.46 - 24.09	

When ready to perform the readings the participant was instructed to perform the paraspinal extensor endurance test, and timed using the Neuro Trac™ ETS PC program, to determine how long they were able to hold this position for, using the tactile feedback method. The Neuro Trac™ ETS PC program was only activated by the researcher once the participant had made contact with the rope, a break in contact with the rope indicated the end of the test, and the Neuro Trac™ ETS PC program was stopped immediately. The Neuro Trac™ ETS PC program simultaneously recorded the mean microvolts (mVs) in order to determine the paraspinal muscles activity.

The participant remained in the prone position for 15 minutes following performing the paraspinal extensor endurance test, to allow for recovery from fatigue (Larivière, Gravel, Arsenaul, Gagnon and Loisel, 2003) prior to the interventions being applied. Both interventions were applied in the prone position. SI joint manipulation was administered by the research assistant utilising the Impulse Adjusting Instrument (Colloca and Keller, 2009). The Force Adjustment Switch was placed in position 3, this activated the high force setting which administered 400 Newtons in rapid pulse mode and is recommended for the SIJ (manual). It was placed over the involved posterior superior iliac spine, and using an anterosuperior and medial to lateral line of drive, the preload was engaged and when the amber light turned to green the electronic trigger was compressed and 12 consecutive thrusts were delivered into the SIJ (6Hz, 2sec) (Colloca and Keller, 2009). Repeated thrusts are used for inducing further joint motion and for resetting neuromuscular reflexes (Introducing Impulse, 2009).

The placebo group, lying in the prone position, had the Impulse Adjusting Instrument placed over their involved posterior superior iliac spine, the preload was activated and when the amber light turned green, a second Impulse Adjusting Instrument was compressed and delivered the lowest thrust (100N) to the body of the research assistant thereby the participant heard the clicking noise, but no actual treatment was delivered to the participant. The participants were naive to having an activator adjustment and were therefore unaware that they did not actually receive a treatment (Symons, Herzog, Leonard and Nguyen, 2000).

Immediately post-intervention, not more than one

minute, the participants in both groups re-performed the paraspinal extensor endurance test and the lumbar spine flexion and extension measures were taken to obtain the post-intervention outcomes.

Statistical analysis

Surface EMG data was recorded as mean muscle activity for the duration of the Beiring Sorensens test and peak amplitude. The raw data was normalised by dividing the post-measure by the pre-measure and multiplying by 100 to get a percentage. The data was analysed, by a qualified statistician, using IBM* Statistical Package for the Social Sciences (version 21) and SATA11. A p value of less than 0.05 was considered as statistically significant. Quantitative variables were assessed for normality using Q-Q plots and Kolmogorov-Smirnov test. The majority of the variables were acceptably normally distributed and met the assumptions to perform parametric tests. Paired t-tests were used to compare pre and post measurements within a group and independent t-tests were used to assess between group differences. The repeated measures ANOVA was used to compare the change in the two time points between the two treatment groups (intervention and placebo) (McCaul, 2014).

Ethical considerations

Participant autonomy was ensure by all participants being given a verbal and written explanation of the study, thereafter they were required to sign informed consent. This study involved a placebo intervention however participants were informed that they had a 50% chance of being allocated into the placebo group. All participants were asymptomatic for pain, thus no treatment was withheld that could result in negative consequences for the participant. If any illness or pathology was diagnosed at the initial consultation or during the research process, the participant was withdrawn from the study and appropriately referred. All participant data was coded ensuring participant confidentiality.

RESULTS

The age range of the participants was 20 to 40 years, with a mean age of 27.38 years, the intervention group had a mean age of 26.95 (±4.63) years and the placebo group 27.8 (±3.96) years ($p=0.537$). There were no significant difference between

Figure 2: Transversus abdominus muscle assessment per group

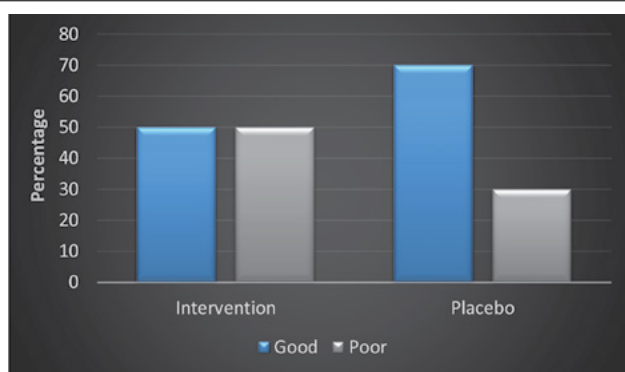


Figure 3: Paraspinal muscle length assessment pre and post-intervention

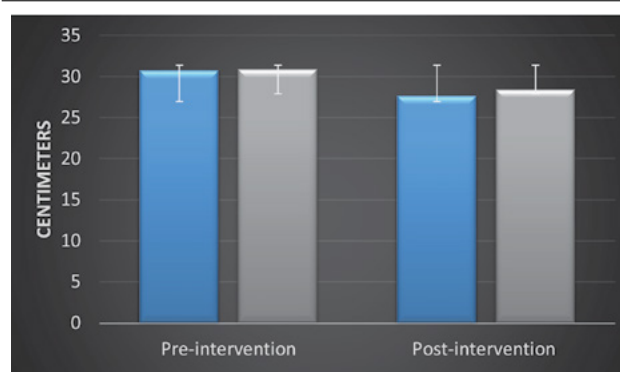


Figure 4: Lumbar extension range of motion pre and post intervention

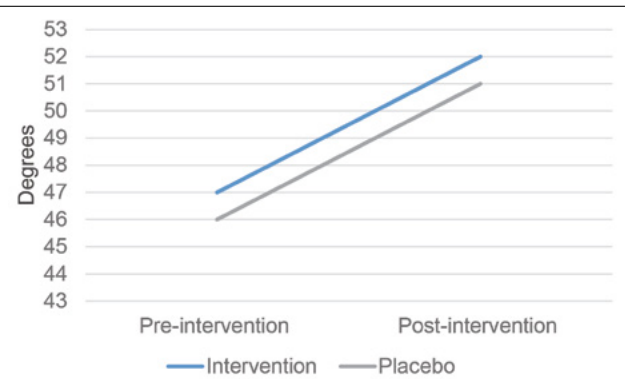


Figure 5: Paraspinal muscle endurance measures pre- and post-intervention

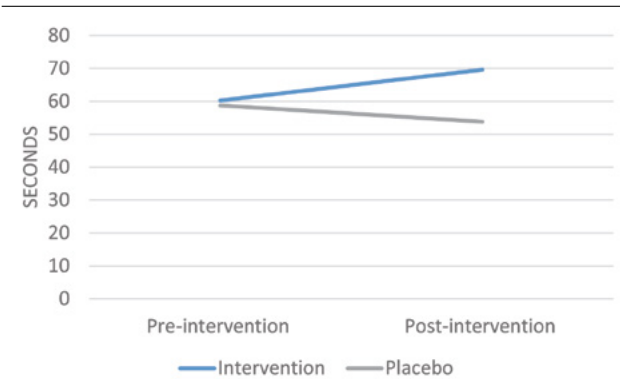


Table 4: Normalised muscle activity readings pre and post intervention

Muscle activity		Intervention		Placebo		P value
		Pre-	Post-	Pre-	Post-	
Channel A	Mean (SD)	100.00	103.52 (8.63)	100.00	109.31 (11.52)	0.080
	Peak	100.00	109.22 (11.78)	100.00	111.84 (15.76)	0.556
Channel B	Mean (SD)	100.00	104.59 (8.99)	100.00	106.01 (9.75)	0.635
	Peak	100.00	113.7 (12.88)	100.00	109.84 (9.71)	0.291

the groups in terms of height, weight or body mass index (BMI) as seen in [Table 3](#). When assessed for ability to activate transversus abdominus muscle there were no significant differences between the group ($p = 0.197$; t-test), as seen in [Figure 2](#), with 60% ($n=24$) of the participants receiving a good rating. The paraspinal muscle length assessment showed that there was no significant difference between the groups at baseline ($p = 0.909$). The intervention group showed a significant decrease in paraspinal muscle length post intervention ($p < 0.001$), while the placebo group had a borderline significant change ($p = 0.05$), when compared there was no significant difference between the groups post-intervention ($p = 0.539$), [Figure 3](#). Lumbar spine flexion and extension range of motion was similar pre-intervention for both groups ($p = 0.980$ and 0.784 respectively). No significant change in flexion occurred post-intervention

($p = 0.919$) but extension increased for both groups ($p < 0.001$) post-intervention, with no significant difference occurring between the groups ($p = 0.876$), as seen in [Figure 4](#).

There were no significant baseline difference between the groups for paraspinal muscle endurance ($p = 0.843$), with a significant difference being found between the groups post-intervention ($p = 0.004$). The intervention group's endurance measures increased as seen in [Figure 5](#). No significant difference was found at baseline measures between the groups for raw muscle activity readings (microvolts) for the channel A, mean ($p = 0.538$) and peak ($p = 0.415$), and channel B, mean ($p = 0.650$) and peak ($p = 0.718$) readings. The normalised data showed that both groups had a significant increase in their peak and mean muscle activity post intervention ($p < 0.05$), increasing between 3 and 13 percent. However there was no significant intervention effect on muscle activity

for channel A mean ($p = 0.080$) and peak ($p = 0.556$) readings, similarly for channel B mean ($p = 0.635$) and peak ($p = 0.291$) measures, as seen in [Table 4](#).

DISCUSSION

The primary function of the paraspinal muscles is to provide stability and control movements of the spine (Moore and Dalley, 2006; Bogduk, 2005). Sufficient endurance of these muscles is important for good health, and is often taken for granted (Moffroid, 1997). Reduced trunk extensor endurance has been linked to mechanical low back pain (Biering-Sorensen, 1984, Demoulin *et al.*, 2006; Bernard *et al.* 2008). The Biering-Sorensen extensor endurance test has been described as the gold standard for assessing the isometric endurance of the trunk extensor muscles (Moreau, Green, Johnson and Moreau, 2001; Demoulin *et al.* 2006). In this study the participants were asymptomatic yet their test time improved following SMT.

Spinal manipulative therapy (SMT), both manual and Activator assisted, in symptomatic and asymptomatic participants (Herzog *et al.*, 1999; Symons *et al.*, 2000; Colloca and Keller, 2001), has been associated with neuromuscular reflexes. Several studies have shown short-term inhibition of alpha motoneuronal excitability in the lumbar region following SMT (Dishman and Bulbulian, 2000; Dishman *et al.*, 2002; Dishman and Burke, 2003; Dishman *et al.*, 2005; Fryer and Pearce, 2012). The finding in this study contrast this as those participants receiving SMT had a significant decrease in their paraspinal muscle length post-intervention together with no significant change in muscle activity. Harvey and Descarreaux (2013) measured muscle activity of the paraspinal muscles during lumbar flexion-extension movements before and after SMT and found that the control group had significant increases in muscle activity during the 30 minute post-test compared to the SMT group. Indicating that SMT may alter the recruitment ability of the paraspinal muscles and that the repeated movements may have caused fatigue, and SMT may have improve the ability of the muscle to resist the fatigue, thus resulting in no increasing muscle activity in the intervention group.

The paraspinal muscle activity in both groups slightly increased with no significant intervention effect being observed. Keller and Colloca, (2000) found that following manually assisted SMT to the thoracolumbar spine, SIJ and sacrum there was a significant ($p < 0.001$) increase in muscle activity during isometric trunk extension maximum voluntary contractions (MVCs) of the paraspinal muscles when compared to a placebo and control group. Indicating that SMT altered the muscles functional ability. Suter, McMorland, Herzog and Bray (2000) and Suter and McMorland (2002) found following SIJ manipulation that there was a decrease in muscle inhibition and short term increase in muscle strength. These studies indicate that SMT may lead to a change in sensory input, resulting in altered motor output at that segmental level. This changed

motor output was observed as increased muscle strength and hence improved functionality of these muscles. When the intervention group was compared to the placebo group in this study a significant increase in paraspinal endurance time occurred only for the intervention group. Indicating that SMT may have either altered the inhibited state of the paraspinal or allowed more motor units to be recruited and thus improved endurance time. The Bering Sorensens test may be affected by the functioning of the core musculature. The core musculature is important in controlling functional stability around the trunk and spine (Akuthota and Nadler, 2004), thus those who had a well-functioning core may have had a greater ability to hold the test position thus getting a better score. A "good" core was not an inclusion criteria but it was assessed using the prone transversus abdominus test developed by Richardson *et al.*(1999). If the core musculature is working sub-optimally, the paraspinal muscles may become overloaded, resulting in fatigue and reduced ability to perform an isometric extension contraction. Thus it is possible that core strength may have affected the results of the study, even though no significant differences were found between the groups with regards to this assessment.

The placebo utilised in this study may have stimulated the cutaneous skin receptors due to its contact with the skin. It has been reported that cutaneous receptors are not likely to be involved in the changes mediated by SMT (Murphy *et al.*, 1995). Pickar and Wheeler (2001) found that muscle spindles have a resting discharge prior to SMT which increased 30% during the preload phase of SMT and 200% during the impulse thrust, whereas the Golgi tendon organs (GTOs) were generally silent during rest and in the preload part of the SMT, and only fired during the impulse thrust. Indicating that the changes observed in the placebo group were unlikely as a result of cutaneous mechanoreceptor activity and may be more related to the tasks preformed during the study. Both groups had increased paraspinal muscle activity and improved lumbar spine extension post-intervention. It is possible that the research protocol accounted for these changes, however the improved endurance time was unique to the SMT group indicating that mechanoreceptor firing into the spinal cord and changes to the motor neuron pool may have been responsible for this outcome.

Limitations

The surface electromyography used in this study was a biofeedback machine, which is primarily used in the clinical environment and not for research purposes. Manual therapists and biokinetics often use this equipment in re-training motor function. A research designed surface electromyographic instrument may have more filtration of 'noise' and may produce a more reliable signal.

Recommendations

The results seen in this study are promising and require

verification in a study with a larger sample and using a surface electromyographic instrument developed for research purposes. This study should also be repeated on a symptomatic low back pain population to determine if the same outcome would be found.

Contribution to the field

The neurophysiological effects of spinal manipulation have received much attention in the literature. This study adds to a growing body of knowledge that shows that spinal manipulation can affect muscle functioning, yet further studies are required to further understand how these effects occur and their clinical significance.

CONCLUSION

A growing body of knowledge shows that following SMT there are neurophysiological changes that occur. The impact of these changes is yet to be fully understood. This study adds to this knowledge base showing that post-manipulation there are functional changes in the paraspinal muscles when compared to a placebo intervention.

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The effect of Power®ball on non-specific wrist pain

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ABSTRACT

Purpose: The aim of this study was to determine the effect of using the Power®Ball gyroscope as a treatment device, with regards to pain and change in endurance in the wrist for participants with a non-specific wrist injury. The aim was determined by using the Jamar Dynamometer grip strength measuring instrument and the Patient Rated Wrist Evaluation Questionnaire.

Method: The study consisted of 40 participants that had an equal male to female distribution. The individuals had to be between the set ranges of 18 to 35 years of age to prevent any discrepancies regarding the participant's grip strength and had to meet the inclusion and exclusions criteria before being accepted into the study. The participants had to use the Power®Ball gyroscope for 5 minutes per treatment session.

Procedure: Treatment consisted of 12 treatment sessions and was carried out 3 times per week so that the treatment time period occurred over a four week study period. Participants were required to complete the objective and subjective data before the 1st, 7th and 12th treatment sessions. The objective data were recorded by using the Jamar Dynamometer to record the change in grip strength for each participant throughout the study. The subjective data were gathered by using the Patient Rated Wrist Evaluation Questionnaire. Participants then used the Power®Ball gyroscope in the hand with the affected wrist. All data recorded were gathered under the supervision of the researcher and analysed by a statistician at the University of Johannesburg.

Results: Significant findings were present for both the Patient Rated Wrist Evaluation Questionnaire and the Grip strength measurements with the Jamar Dynamometer. A constant, significant decrease in pain was noted throughout the study but the most significant changes occurred between the 7th and 12th treatment sessions. A significant increase in grip strength was also noted throughout the study with the greater increase in grip strength occurring during the first 7 treatments.

Conclusion: The results of this study suggest that the Power®Ball gyroscope has a positive effect on the treatment and rehabilitation of non-specific wrist pain. The possible effect/outcome for the chiropractic profession suggest that the Power®Ball may be used as an alternative, conservative treatment modality or in conjunction with an existing treatment protocol for treating sub-acute or chronic non-specific wrist pain. Additionally the results indicated that the Power®Ball may serve as a grip strengthening or endurance device to prevent future injury to the wrist.

INTRODUCTION

Although hand and wrist injuries are not hazardous to a person's wellbeing, they are of great importance in terms of our average daily living (Wang, Reed, Leone, Bhandari and Moro, 2001). Almost every professional career relies on the optimum function of the worker's wrists to complete a certain function. Wrist pain may hinder athletes from lifting weights, throwing a javelin, swinging a tennis racquet or holding a bicycle handle. Wrist pain may also be an irritation in professions where hands are constantly used, such as in the case of chiropractors, physiotherapists, secretaries and typists.

Any anatomical structure under constant stress will often lead to injury. However, because of the complicated anatomy of the wrist, the close relationship of multiple bones and ligaments in the wrist and subtle imaging findings, the pathophysiology may appear vague and not related to a single structure (Vezeridis, Yhosioka, Han and Blazar, 2009). Abnormal biomechanics and repetitive motions across the

wrist joint may lead to pain and dysfunction. Wrist pain may be a result of both traumatic and non-traumatic events. Traumatic wrist injuries may lead to possible fractures and dislocations, while non-traumatic wrist injuries may develop from muscle, ligament and tendon dysfunction, which may lead to injuries such as tenosynovitis, nerve entrapment and arthritis (Wang *et al.*, 2001)

From a health clinician's perspective, difficulty arises in the treatment and rehabilitation of the injury if the pathophysiology of the injury is not understood. A vast amount of conservative treatment options and devices are currently available for wrist pain, although research on the treatment of wrist pain is limited in the cases where fractures and surgery are excluded. One such conservative treatment device available is the Power®Ball gyroscope.

The Powerball™ is based upon the principles of a gyroscope, which focus on exercising muscular build-up of the upper extremities. Research has shown that exercise with the Power®Ball increases the muscle endurance substantially over

a one month period as well as highly increases the number of contractions of the forearm muscles. The Power®Ball acts as an eccentric exercise tool, generating forces in different directions and thus causing stimulation of the forearm, hand and wrist musculature (Balan, Garcia-Elias, 2008).

The aim of this study was to determine the effect of utilising the Power®Ball gyroscope as a treatment device, specifically for pain and change in endurance in the wrist for participants with a non-specific wrist injury. The aim was determined by using the Jamar Dynamometer as an objective measurement device and the Patient Rated Wrist Evaluation (PRWE) questionnaire as a subjective measurement.

The study determined the proficiency and effectiveness of the Power®Ball as a treatment or rehabilitation tool for non-specific wrist pain. The outcomes of the study will provide healthcare clinicians with an alternative, conservative treatment protocol for treating non-specific wrist pain. Additionally, the results indicate that the Power®Ball may serve as a grip strengthening device to prevent future injury to the wrist.

METHODOLOGY

Selection Criteria

Participants were recruited from the University of Johannesburg Campus, gymnasium and different University of Johannesburg sport associations such as golf, tennis, rugby and athletics clubs. Participants from businesses where the employee's wrists are under constant stress were also invited to partake in the study. Recruitment was done via word of mouth and by means of advertisement leaflets placed in the area surrounding the University of Johannesburg's Doornfontein Campus, and was approved by the Faculty of Health Sciences Research Ethics Committee (clearance number REC-01-161-2015).

The research sample consisted of forty participants, selected via simple random sampling. The participants who wanted to participate in the study were between the ages of eighteen to thirty five. Twenty males and twenty females were recruited to ensure equal gender ratios. The participants were informed of the nature of the study and evaluated according to the inclusion and exclusion criteria. A hand and wrist examination was performed to assess the injury. Participants read and signed the participant information and informed consent forms, which outlined the purpose of the study and the treatment process and protocol.

Inclusion Criteria

- Male or female participants.
- Participants between the ages of eighteen to thirty five, because a study done by Angst, Drerup, Werle, Herren, Simmen and Goldhahn (2010) showed grip strength remains constant between 18 to 35 and starts declining thereafter.
- Participants who presented with non-specific pain over

the wrist region.

- Participants who presented with decrease grip strength in the injured wrist compared with the average grip strength for the participant's age and gender (Massy-Westropp, Gill, Taylor, Bohannon and Hill, 2011).

Exclusion Criteria

- Participants who experienced a recent traumatic injury to the wrist, hand and/or forearm.
- Participants with recently diagnosed fractures, including acute Boxer's, Colle's and carpal bone fractures.
- Participants experiencing pain during the use of the Power®Ball.
- Participants who were being treated by another practitioner during the study period, including any form of physical therapy that may have affected the wrist.

First visit

The participants were randomly selected, via simple random sampling to participate in the study. Each participant received a participant information and consent form. These forms were discussed with the participant in detail and were signed by the participant after he or she fully understood the aim of the research. During the first visit, a thorough case history and physical examination were performed. Thereafter, a hand regional examination was performed and a patient rated wrist evaluation (PRWE) questionnaire was provided to each participant to complete in order to assess his or her wrist's condition. The PRWE questionnaire formed part of the subjective data collected. An initial grip strength measurement was also taken, using the Jamar grip strength dynamometer, to assess the severity of the condition and the participant's current grip strength. The grip strength data formed part of the objective data and was documented prior to the treatment session by the researcher. The participant was introduced to the Power®Ball gyroscope and received a demonstration on how to use the gyroscope: the Power®Ball was to be used with the participant's arm at the side of the body with the elbow flexed to 90 degrees, in order to isolate the forearm musculature and prevent the use of shoulder muscles. Once the participant was accustomed to the device, the treatment session could begin.

The participants used the Power®Ball for five minutes in the affected hand. The number of revolutions produced during the five minute treatment session on the affected side was recorded with the Power®Ball on-board digital counter and documented by the researcher on the participant objective data collection form. Participants were not allowed to sit in a close proximity to each other during the treatment sessions to prevent any competition that might have arisen. The first treatment session took thirty minutes to complete.

Follow-up visits

Follow up visits occurred during the next four weeks, with

Table 1: Pairwise Comparisons for Patient Rated Wrist Evaluation Score

PRWE(a)	PRWE(b)	Mean difference (a-b)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	6.14	0.74	0.00	4.29	7.99
	3	18.06	1.19	0.00	15.09	21.04
2	1	-6.14	0.74	0.00	-7.99	-4.29
	3	11.93	0.89	0.00	9.69	14.16
3	1	-18.06	1.19	0.00	-21.04	-15.09
	2	-11.93	0.89	0.00	-14.16	-9.69

Table 2: Test Statistics for Grip Strength

	GSD7 - GSD1	GSD12 - GSD1	GSD12 - GSD7
Z	-3.926	-5.07	-2.52
Asymp. Sig. (2-tailed)	0.00	0.00	0.01

Table 3: Pairwise Comparisons for Power®Ball Readings

(I) P	(J) P	Mean difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	7	-34.70	5.63	0.00	-55.27	-14.13
	12	-44.43	5.31	0.00	-63.82	-25.03
7	1	34.70	5.63	0.00	14.13	55.27
	12	-9.73	3.64	0.73	-23.04	3.59
12	1	44.43	5.31	0.00	25.03	63.82
	7	9.73	3.64	0.73	-3.59	23.04

Table 4: Multivariate Test for Power®Ball Readings

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Wilks' Lambda	0.27	7.08	11.00	29.00	0.00	0.73

Table 5: Descriptive Statistic Patient Rated Wrist Evaluation Score

Session/Visit	Mean	Standard Deviation	N
PRWE1	31.96	12.82	40
PRWE7	25.83	13.12	40
PRWE12	13.9	10.48	40

PRWE = Patient Rated Wrist Evaluation

Table 6: Descriptive Statistics for Grip Strength

	N	Mean	Std. Deviation	Minimum	Maximum
GSD1	40	37.13	12.43	20.33	62.00
GSD7	40	41.00	12.76	19.00	67.00
GSD12	40	42.41	13.09	24.00	74.33

Figure 1: Descriptive Statistics for Power®Ball Readings

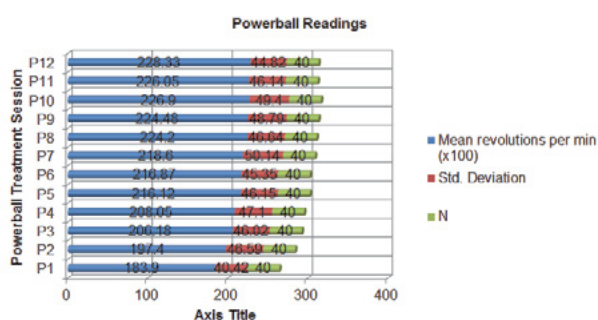
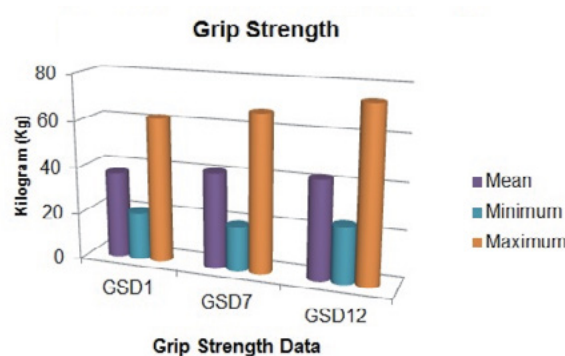


Figure 2: Descriptive Statistics for Grip Strength



three treatment sessions per week, each lasting ten minutes. Sessions two to six consisted of five minute Power®Ball treatments followed by the documentation of the number of revolutions done on the digital counter. On the seventh treatment, the grip strength of the concerned wrist was re-measured with the Jamar dynamometer before the treatment session commenced, and the PRWE questionnaire was completed again by the participant. The participant continued with the five minute treatment session and the number of revolutions was documented. Sessions eight to eleven progressed in the same manner as sessions two to six. The twelfth treatment session was conducted in the same manner as session seven described above: the participant’s grip strength was measured before the treatment session with the Jamar dynamometer followed by completion of the PWER questionnaire. The participant’s wrist was re-assessed before each treatment to document the changes that had occurred since the last treatment.

RESULTS

The One-way Repeated Measures ANOVA Test was used to analyse the data collected, and indicated that an improvement of pain was present over the period of 12 treatment sessions. According to [Table 1](#), a greater mean difference was noted between the 2nd and 3rd PRWE scores than the 1st and 2nd scores. This result implies that a constant decrease of pain was noted from using the Power®Ball gyroscope and that most of the benefits occurred after treating a participant for 7 treatments or more. A significant p value of 0.00 was present throughout all three recordings. [Table 1](#) also illustrated that a significant effect from PRWE score 1 on the 1st treatment session and score 3 on the 12th treatment session was noted. The One-way Repeated Measures ANOVA Multivariate Test summarized that Wilks’ lambda = 0.14, F (2, 38) = 144.87, $p \leq 0.00$, multivariate partial eta squared = 0.86.

The Wilcoxon Signed Rank Test was used to analyse the change in grip strength by means of measurement with the Jamar dynamometer. [Table 2](#) illustrated that the difference between grip strength measurements 1 and 7 and the difference between grip strength measurements 1 and 12

was less than 0.00 ($p \leq 0.00$) and statistically significant. The difference between grip strength measurements 7 and 12 was recorded as 0.01 and statistically significant. It may be concluded that the Wilcoxon Signed Rank Test revealed a statistically significant increase in grip strength following the 12 Power®Ball treatment sessions and can be summarized as $z = -5.07$, $p < 0.00$ with a large effect size ($r = 0.8$). The mean score increases from GSD1 ($m = 37.13$) to GSD12 ($m = 42.4$). From the recorded data, it can be noted that a larger increase in grip strength was noted within the first 7 treatments compared with a relatively small increase from treatments 7 to 12.

One-way Repeated Measures ANOVA analysis was used to measure the each participant’s total number of revolutions achieved while using the Power®Ball during each treatment session. [Figure 1](#) indicated a mean increase in recorded revolutions from treatment session 1 to treatment session 12. A mean value of 183.90 was recorded on the 1st session, which increased to 218.60 on the 7th session and 228.33 on the 12th session. Thus, an increase mean percentage of 15.87% was noted from the beginning of the study to the 7th treatment and an increased mean percentage of 19.46% was noted from the 1st treatment to the last treatment session. Pairwise Comparisons ([Table 3](#)) was found to be significant between the 1st and 7th and 1st and 12th readings ($p \leq 0.00$). Recorded data between the 7th and 12th treatment sessions was statistically insignificant ($p \leq 0.73$). A Multivariate Test ([Table 4](#)) indicated that a large effect size occurred over the period of 12 treatments and may be summarized as Wilks’ lambda = 0.27, F (11, 29) = 7.08, $p \leq 0.00$, multivariate partial eta squared = 0.73.

DISCUSSION

Demographic Data

The study population consisted of 40 participants, with an equal ratio of 20 males and 20 females. The gender group displayed no variation regarding the test for normality and displayed no statistical significance involving the gender distribution. The age range for the study population consisted

of participants between 21 and 28 years of age, with a mean age of 25.58 years.

Pain and disability

Each participant was instructed to complete a PRWE questionnaire on the 1st, 7th and 12th treatment sessions. This data provided a numerical score out of 100 to describe what the participants were experiencing throughout the study. While analysing this score (Table 5), it was noted that a constant decrease in non-specific wrist pain was noted. A small decrease in mean percentage of 19.8% was noted during the first 7 treatment sessions, with a more constant decrease in mean percentage of 46.19% from treatment session 7 to the final treatment (session 12). The participants began with a mean PWRE score of 31.96 and ended with a mean score of 13.9.

Pull and Ranson (2006) stated that eccentric training demonstrated a positive effect in the prevention of ligamentous or tendinous damage and injury. The authors further state that there was also considerable evidence that eccentric contractions might induce a protective effect, called a repeated bout effect, to reduce the likelihood of further exercise-induced muscle damage. Neural adaptation produced by eccentric muscle exercise could also contribute to the repeated bout effect. This neural adaptation seems to be related to a more efficient motor unit recruitment patterns produced by eccentric training.

Hagert (2010) stated that eccentric exercises, such as using the Power®Ball, are designed to create an opposing load to the muscles involved in the exercise, thus lengthening these muscles and ultimately increasing the muscle's strength. Eccentric exercise is mostly used in the rehabilitation of tendinopathies and chronic ligamentous injuries, where it was shown to significantly decrease pain while building tendon strength. The increase in grip strength, which will be discussed in the following section, in conjunction with the decrease in energy consumption of using an eccentric exercise tool and the decrease in perceived pain after treatment with the Power®Ball in this study, resonates with this statement by Hagert (2010).

Grip strength

In Table 6 and Figure 2, a mean increase from 37.13 kg to 41.00 kg was noted from grip strength measurement 1 to measurement 2. A mean increase was then noted from the 41.00 kg grip strength measurement 2 to 42.41 kg grip strength measurement 3. This result indicated a mean percentage increase in grip strength of 9.44% between grip strength measurement 1 and 2, a mean percentage increase of 3.34% between grip strength measurement 2 and 3 was noted and an overall increase in mean percentage of 12.45% was recorded.

A study done by Balan and Garcia-Elias (2008) also concluded that there was a tendency for participants to increase their maximum grip strength while using the Power®Ball. The study was done to ascertain the utility of the

Power®Ball in the invigoration of the forearm musculature and to determine if the increase in maximum grip force and muscular endurance was possible. Ten asymptomatic adults used the Power®Ball gyroscope twice a day for 4 weeks and were measured by using the Jamar dynamometer. The participants were measured again after a 4 week resting period. An increase in maximum grip strength was noted, with a highly statistically significant increase in muscle endurance. The 15% increase in grip strength in Balan and Garcia-Elias' study correlates with the change in grip strength found in this clinical trial (12.45%). The muscle endurance remained slightly unchanged after the 4 week resting period without using the Power®Ball gyroscope. The authors further state that the multidirectional force generating properties of the Power®Ball may be useful in the treatment of patients with acquired or congenital hyperlaxity, having developed wrist dysfunction secondary to weak proprioceptive neuromuscular control, which was included in this study of the effect of Power®Ball on non-specific wrist pain.

Power®Ball on-board digital counter readings

The steadily increase in Power®Ball readings may be attributed to the participants' increase in endurance and co-ordination. Co-ordination is an important aspect of our everyday activities and is achieved by various combinations and degrees of complex movement (Serrien, 2007). Synchronization between the sensory and motor system is important in producing stable coordination patterns. By performing a repetitive specific motion in a coordinated manner, a smooth and controlled coordinated movement is produced (Torre and Delingnieres, 2008). As previously stated by Balan and Garcia-Elias (2008), Power®Ball exercise creates a significant increase in forearm musculature's endurance, which will remain relatively constant for a period of 4 weeks after no activity. In Balan and Garcia-Elias's study, the endurance was established by asking the volunteers to alternate between periods of maximal contraction and periods of relaxation. In this study of the effect of Power®Ball on non-specific wrist pain, the endurance was measured by the number of revolutions the participants can produce while maintaining a slow and comfortable pace without causing pain or any discomfort. Close attention was paid to ensure that these parameters were maintained. Balan and Garcia-Elias stated that although no participants experienced any discomfort or pain during the trial, eccentric exercise in weak or improperly trained musculature has a potential for higher pain index and damage of the muscular ultrastructure (Balan and Garcia-Elias, 2008). However, later studies done by LaStayo *et al.* (2013) stated that evidence exists that eccentric exercise training can be used safely and effectively in rehabilitation. The steadily increase in the number of revolutions acquired with the Power®Ball throughout this study showed that an increase in endurance and grip strength is achieved with the presence of a decline in pain perception.

CONCLUSION

The aim of this study was to determine the effect of using the Power®Ball gyroscope as a treatment device for pain and change in endurance in the wrist for participants with a non-specific wrist injury. Whether or not the aim was achieved was determined by using the Jamar dynamometer as an objective measurement device and the PRWE questionnaire as a subjective measurement.

The changes in this study could have been brought on by the positive effects of the use of an eccentric exercise device causing stretching of a muscle, tendon or ligament without causing an increase in the reduction of energy and thus increasing the endurance of the muscle. The presence of the repeated bout effect increases the neural adaptation surrounding the wrist joint and prevents further structural damage or injury. It is also stated by Zeppetzauer *et al.* that eccentric endurance exercise has an effect on metabolic and inflammatory risk factors thus decreasing the level of pain perception.

Hagert (2010) believes that eccentric exercises, such as using the Power®Ball, are designed to create an opposing load to the muscles involved in the exercise, thus lengthening these muscles and ultimately increasing the muscle's strength which leads to an increased endurance of the structure.

Pull and Ranson (2006) stated that eccentric training demonstrated a positive, beneficial effect in the prevention of ligamentous or tendinous damage and injury. The authors' further state that the eccentric contractions induce a protective effect, called a repeated bout effect, to reduce the possibility of further exercise induced muscle trauma. Neural adaptation generated by eccentric muscle exercise could also contribute to the formation of the repeated bout effect. This neural adaptation seems to be associated with a more dynamic motor unit recruitment pattern produced by eccentric training. In addition, LaStayo, Marcus, Dibble, Frajacomio and Lindstedt (2013) found when a muscle is stretched while contracting; the energy released by the muscle is reduced.

A study conducted by Zeppetzauer, Drexel, Vonbank, Rein, Aczel and Saely (2013) found that eccentric endurance exercise economically improves metabolic and inflammatory risk factors with a decrease in serum levels of C-reactive protein and creatine kinase activity noted within 45 healthy, sedentary individuals. In addition, a study done by Tyler, Thomas, Nicholas and McHugh (2010) found that using an eccentric exercise device combined with a standard treatment for chronic lateral epicondylitis found that a considerable decrease in pain and increase in grip strength was noted.

The results of this study suggest that the Power®Ball gyroscope has a positive effect on the treatment and rehabilitation of non-specific wrist pain. Statistically significant differences were found in the reduction of pain over the course of 12 treatment sessions and an increase in grip strength during the first 7 treatment sessions, with a small increase of grip strength over the last 5 treatments. A statistically significant increase of Power®Ball revolutions

was recorded for the first 7 treatments, thus indicating an increase in endurance during these treatment sessions.

The possible effect/outcome for the chiropractic profession is that the Power®Ball may be used as an alternative, conservative treatment modality or in conjunction with an existing treatment protocol for treating sub-acute or chronic non-specific wrist pain. Additionally, the results indicated that the Power®Ball may serve as a grip strengthening or endurance device to prevent future injury to the wrist.

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