INTERNATIONAL RESEARCH JOURNAL OF PHYSICAL EDUCATION AND SPORTS SCIENCES
ISSN: 2394 –7985 PEER REVIEWED ONLINE
VOLUME: IX ISSUE: II FEBURARY-2022
Bi –Annual
International Peer Reviewed, Refereed & Indexed Research Journal

THE BIOMECHANICAL, ELECTROMYOGRAPHICAL, PULMONARY, PROPRIOCEPTIVE AND PROPHYLACTIC BRACING INFLUENCES OF CRANIAL LOADING ON FEMALE PUBESCENTS RESIDING IN THE GLENDALE REGION OF KWA-ZULU NATAL, SOUTH AFRICA: A CONCEPT PAPER




Ellapen TJ* **Paul Y*** **Kurten M*** **Tebogo Motaung***

*Tshwane University of Technology, Department of Sport Rehabilitation and Dental Sciences, Pretoria West Campus- SOUTH AFRICA
Corresponding Author: Terry J Ellapen @tellapen1@yahoo.com

ABSTRACT

Background: Many rural South Africans transport firewood, water and food through the medium of head/cranial loading. There has being nine investigations conducted in Africa identifying the ill effect of cranial loading on the porter's posture, on small samples, which needs validation. No investigations examining the pulmonary and proprioception response to cranial loading in rural South African communities has being undertaken. Method/Design: A cross-sectional pre-test post-test cross-over, quantitative research study design will be employed. Participants will be randomly assigned into an experimental (n=50) or control (n=50) group. The experimental group will carry the cranial load, while the control group will not. In the cross-over phase when the pre-test control becomes the experimental group, they will also carry their daily cranial load. All participants' anthropometry, posture (craniovertebral (CVA), craniohorizontal (CHA) and standing pelvic angles (SPA)) will be measured during both phases. Posture will measure with the visual New York Posture Rating Chart, the manually measuring of the aforementioned angles and through Smartphone application technology and an electronic camera. Electromyographical measures of the participants' cervical and lumbar extensors and flexors will measure during loading and unloading phases. The loaded and unloaded pulmonary and proprioception response will be measured. Finally, the energy expenditure of cranial load external masses will be compared to equivalent backpack external loads to determine energy efficiency. The aforementioned methodology describes phase one of the study. In phase two of the study, a medical orthotic brace will be used as an intervention to determine its efficacy to dissipate vertebral pain, maintain an anatomical better aligned sagittal plane posture, the aforementioned selected kinathropometrical measures and cervical and lumbar flexor and extensor activity.

INDEXED BY:
INTERNATIONAL SCIENTIFIC INDEXING (ISI)-UAE, ASI- ADVANCED SCIENCES INDEX-GERMANY
&
INTERNATIONAL SOCIETY FOR RESEARCH ACTIVITY (ISRA)-INDIA
IRJPESS Impact Factor (ISRA: JIF): 1. 947 & SJIF: 6.334
Website: www.sportjournals.org.in

Discussion: The validation of the reliability of the Smartphone application technology to measure posture will serve as a cost-saving method to accurate measure posture in rural South African communities. The findings of the pulmonary and proprioception will be novel evidence that will be used to better understand the impact of cranial loading on the porter's health and well-being. In faze two the reliability of prophylactic medical orthotic cervical and lumbar bracing to maintain better sagittal plane posture and alleviate neuro-musculoskeletal pain. Further, the efficacy of habitual strengthening exercises to combat misaligned posture and alleviate neuro-musculoskeletal pain and injury will be investigated.

Keywords: cranial loading, rural, musculoskeletal, proprioception & pulmonary.

INTRODUCTION

Many rural African societies' still continue with traditional method of cranial/head loading and it subsequent carriage of firewood, water and food (Echarri & Forriol, 2002; Porter *et al.*, 2013). The habitual retrieving of firewood and water is the responsibility delegated topubescents females within society (Porter *et al.*, 2013). Young girls from the age of five years begin carrying cranial loads of 3kg, which is steadily increased to heavier loads paralleling their anatomical development. "*Building-up body capital*" is the process adopted by theseruralparents to gradually increase the cranial load mass to evenly correspond with the child's growing muscle strength, endurance, and cardio respiratory endurance. Maximum cranial loads can weigh as much as 35kg. Once girl ages 15 years, she is expected to carry adult cranial loads of approximately 25kg, over distances ranging from two to 10km (Porter *et al.*, 2013). In the absence of girls within a family, then the adult females take on the responsibility of retrieving water, firewood and food predominantly using cranial loading as a method of transportation of these items. Gajdosik *et al.*(1985) and Porter *et al.*,(2012) explained that cranial loading porter age serves as a rite of passage among rural South African societies. Carrying of heavy adult cranial loads is considered a sign of maturity, which increases the pubescent status within the bucolic community (Gajdosik *et al.*, 1985; Porter *et al.*, 2012).The individual's financial value geometrical increases as she is seen as an industrious contributor to the wellbeing of the family and community, which increases her wedding dowry. In spite of these social benefits, habitual cranial loading does produce injurious neuro-musculoskeletal consequences. Unfortunately, the responsibility of daily carrying water and firewood often makes the children late for school and/or result in premature resignation of all scholastic endeavors. Echarri and Forriol (2002; 2005) and Ellapen et al. (2009) have reported the occurrence of cervical and lumbar neuro-musculoskeletal pain. Cranial loading narrows the intervertebral disc spacing, causing intervertebral disc impingement and spondylolisthesis. Echarri and Forriol (2002 & 2005) recorded radiographic vertebral imagery that changed during cranial loading versus unloaded phases. A drawback of this type of investigative protocol is the high financial cost, which limits the sample size to be small. The findings of small sample sizes question their power of significance, because critics question whether the sample was truly representative of the larger population. Therefore, an auxiliary pragmatic cost-effective test such as electronic kinematic analyses through digital camera and Smartphone has being recommended. Validation of the reliability of this cheaper pragmatic test to identify excessive cervical and lumbar postural lordosis will be beneficial for early identification of spondylolisthesis, through the identification diminished CVA and CHA.

This clinical kinematic investigation will measure the change in CVA, CHA and SPA posture due to cranial loading through the use of manual measuring, digital imagery captured by both Smartphone application and electronic camera(this is a novel idea). The analyses of these biomechanical angles will enhance our understanding how cranial loading alters cervical and lumbar vertebral alignment, and the path mechanics of cranial loading induced spondylolisthesis. The postural analyses will be measured through multidimensional approach: visual observation using the New York Posture Chart (McRoberts *et al.*, 2013), manual goniometry and digital imagery through Smartphone application and an electronic camera. These methods will be used to compare for intra-tester and inter-tester reliability and validity. This is an attempt to find a cheaper pragmatic alternate to expensive radiographic imagery. To further explain the change in sagittal plane kinematic posture during cranially loaded versus unloaded phases, electromyography (EMG) measures of cervical and lumbar extensors and flexors will be recorded. The postural and EMG measures will be used to explain the neuro-musculoskeletal pain experienced at the cervical and lumbar regions as cited in the three previous studies (Echarri & Forriol, 2002; 2005; Ellapen *et al.*, 2009).

The anthropometric changes in the standing vertex and acromionale heights during cranially loaded and unloaded phases has been used to explain cervical intervertebral disc compression by Ellapen *et al.*(2009) on a small sample (n=20). However, validation of these findings is required. Electromyography (EMG) measures of cervical and hip flexors and extensors during cranial loaded versus unloaded phases will provide clarity on the path mechanism of altered vertebral posture and associated neuro-musculoskeletal pain (intervertebral disc compression). This proposed study will use electromyography (EMG) measures that will validate the claim whether cranial loading creates an asymmetrical force couple between cervical and lumbar extensors and flexors, which assists intervertebral disc compression.

There has also being empirical research investigating the energy cost of cranial loading porter age (Lloyd *et al.*, 2010a; Lloyd *et al.*,2010b; Lloyd *et al.*, 2010c). The individual's physical conditioning influences human energy expenditure (aerobic capacity, muscle strength and endurance) body composition (percentage of fat free mass, fat mass, total body mass, somatotype and size) and the environment (terrain, weather: wind, cold, heat and rain). A heavier mass person induces a higher basal metabolic rate and physical activity energy expenditure as compared to a leaner, lighter massed person (McArdle *et al.*, 2010).The seminal empirical investigations of Maloiy, Hegland, Prager *et al.* (1986) and Charteris, Nottrodt, Scott *et al.* (1989) examined the energy expenditure of cranial loading among rural African porters. Maloiy *et al.* (1986) reported that African female porters have the remarkable capability to carry loads of up to 20% of their body mass with a metabolic cost equal to that of unloaded walking metabolic cost. Charteris *et al.* (1989) concurred this phenomenon among South African rural adult females, describing it as the "*free ride hypothesis*". A critical limitation of these studies was the small sample sizes, alluded to by Lloyd *et al.* (2010a). Lloyd et al (2010a) did not concur with Maloiy et al. (1986) and Charter is et al. (1989) findings, leaving an unresolved question. The energy expenditure aspect of this project aims to finding answers to these unresolved questions.

It is empirically undetermined whether the anecdotal reports of habitual cranial loading limits the incumbent's breathing patterns, such that the aspiratory tidal volume is diminished in an attempt to keep the cranial load balanced and upright. If this anecdotal postulation is true, this will affect the porter's VO_2max and eventually physical activity capacity. From a pulmonary health perspective, does cranial loading produce chronic restrictive pulmonary disorders and/or chronic obstructive pulmonary disorder, which begs an answer? These questions suggest that there is a scarcity of empirical literature that has investigated the effect of cranial loading and porterage on the incumbent's pulmonary function. The impact of cranial loading on the incumbent's proprioception has not being investigated. This research will be the first to explore the ramification of cranial loading and its impact on proprioception, which could be employed explain its predisposing risk to injury such as falls and physical trauma to the porter.

In phase two, the impact of the introduction of braces (cervical and lumbar) and lumbopelvic strengthening exercises will be investigated. It has being postulated that cervical and lumbar bracing will assist porters to maintain a better anatomical aligned posture, which help to alleviate vertebral pain, intervertebral disc compression andspondylolisthesis. Prentice (2011) had reported that habitual strengthening helps to alleviate lower back pain. This study aims to help the community to improve their quality of life.

DESIGN OF THE STUDY

The study will comprise of phase one and two. Phase one of study will persist for five years, with primary aim to establish the impact of cranial loading on the sagittal plane kinematic posture, selected kinanthropometry, pulmonary, proprioception and EMG muscle activity as compared to unloaded. In phase two, prophylactic medical cervical and lumbar orthotics will be introduced to measure its impact on the incumbents' sagittal plane vertebral posture, selected kinanthropometry, pulmonary, proprioception and EMG muscle activity.

Phase One

A cross-sectional pre-test post-test cross-over, quantitative research study design will be used (Figure 1). The research design is a cross-sectional observational experimental study primarily due to fact many of participants often marry and relocate, which makes a longitudinal study tracking of participant difficult to impossible. Participants will be randomly assigned into an experimental (n=50) or control (n=50) group. The experimental group will carry their habitual cranial load, while the control group will not (acute intervention). In the cross-over phase when the pre-test control becomes the experimental group they will also carry their daily cranial load (Figure 1). The Cochran formula was used to calculate the sample size, which equated to 95.4 than was rounded off to 100.

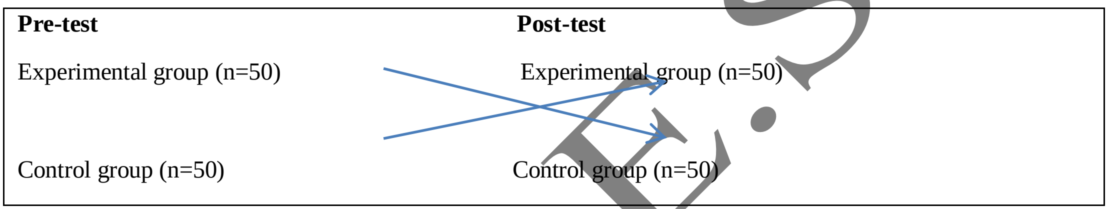

Figure 1. Observational pre-test post-test crossover design

Phase Two

This phase will follow the aforementioned research design, but differs by the introduction of the prophylactic (cervical and lumbar) medical orthotics. The aim of the second phase is determine the efficacy of prophylactic bracing and strengthening exercise as a therapeutic modality to improve the incumbents' quality of life.

Ethical approval and Funding

The phase one of research project was divided into various sub-studies, of, which two have received ethical approval from Tshwane University of Technology. The first study titled: The comparison of the biomechanical and electromyography changes imposed by cranial loads during an unloaded versus loaded phases among children residing in the Glendale (ILEMBE DISTRICT) of KwaZulu-Natal) ethical approval certification is REC2020-12-001. The second study titled: Pulmonary and proprioceptive influence of habitual cranial loading porterage among children residing in the Glendale region of Kwa-Zulu Natal ethical approval certification is REC2020-11-013. The third study titled:The comparative analyses of the head versus backpack mode of loading bearing among the adolescents in Glendale (ILembe District) in KwaZulu-Natal, has being submitted for ethical approval as of present.The researchers have applied for funding the South African National Research Funding for grants. The second phase of the study also involves numerous sub-studies, which will be disseminate into various sub-sections.

Sample size calculation

The Cochran formula is:

$$n_0 = \frac{Z^2pq}{e^2}$$

$$= \frac{(1.96)^2(0.54)(0.46)}{(0.1)^2}$$

$$= 95.45$$

The study will be conducted in rural region of Glendale (Ilembe District), in Kwa-Zulu Natal, South Africa. A purposive sampling procedure will be used to select participants for the study. The study will make the use of the assistance of all graduate students and staff involved in the cranial loading research project from Tshwane University of Technology (TUT). The TUT staff involved in the project has met with the Glendale community leader of the Ilembe District briefing him on the nature of the study and answer all questions he and his counselor presented. Written permission has been obtained from the community leader. A briefing meeting will be held to explain to the community (children and parents) of the nature of the study and answer all questions. The briefing session will be conducted in English and isiZulu (the native language of the community). At the briefing session, the information documentation of study, child ascents and parental informed consent documentation will be disseminated to the community. A community intermediary (who is not involved in the study such as a local priest, religious leader and/or teacher) will be identified and tasked to serve as a liaison between the community members and the researchers. This will ensure that no community members and participants were unduly coerced to participate in the study. A date will be scheduled at the convenience of the members who volunteer to participate in the study, to collect data. All participants will gather at the local community-meeting site (church), where data collection will take place.

On day of data collection, all participants will be welcome and thank for the voluntary participation. An opportunity to answer any questions fielded by the participants and/or their parents will be provided again. A postgraduate research assistant and the local community counselor who are fluent in isiZulu will serve as translators and communicate all information. Data collection procedure will involve completion of cranial loading questionnaire, kinanthropometry, measuring of their daily cranial load, apply electromyography leads cervical and hip flexors and extensors, observing posture during unloaded and loaded phases. Further pulmonary and proprioception measures will be recorded during unloaded and cranially loaded phases. The eligibility criteria of the study include; female pubescent and adolescents that habitually carry cranial loads residing in the Glendale region (Ilembe District) of Kwa-Zulu Natal, voluntarily participation and signed a parental informed consent and child ascent.

Anthropometry

The heights (vertex, acromionale, external radiale, hip, externale tibiale and navicular) and body mass of the participants will be measured with and without the cranial load, then the participant's body mass index (BMI) will be calculated according to the International Society for Advancement of Kinanthropometry (ISAK) procedures (Stewart *et al.,* 2011). Measurements will be taken prior to all other clinical measurements. The following measurements will be taken skinfolds; girths; breadths; lengths. Two sets of measurements will be taken, and the statistical mean will be used (this maintain intra-reliability integrity).The cranial load of each participant will be electronic weighed with an electronic Omron BF214 scale.

Cranial loading Questionnaire

The parents of the younger children and/or the child would need to complete the Cranial Loading Questionnaire (adapted from Ellapen *et al.,* 2009). The questionnaire reviews the cranial load mass carried, the duration, distance, and geographical terrain of carriage and whether the participants experience pain and discomfort during the act of carrying the cranial load, as well as post carriage. The local community counselor and the postgraduate assistant will assist parents to understand any ambiguity in the questionnaire. A pilot study will be conducted to determine the reliability and validity of the adapted questionnaire.

Posture analyses

The participant posture will be recorded with a digital camera (Canon Power Shot SX540 HS), Smartphone application (Angulus) and manual observation in the sagittal and frontal planes. The postural changes induced by the cranial load will determined by comparing the participant's unloaded phase posture with their cranial loaded phase in the corresponding planes, similar to Ellapen *et al.* (2009) protocol. Thereafter comparative analyses of inter-tester reliability will be made, with the intention to eventual determine an easier and cost sparing method of capturing accurate posture when conducting field testing. The participant's identifiable characteristics will be blocked off and each digital image will be assigned the participant's individual numerical reference to maintain confidentiality. Posture analyses will be conducted in a private area/room, thus maintaining privacy. The manual postural observation will record by the adoption of the New York Posture Rating Chart (NYPRC) (reliability score of r=0.77) (McRoberts *et al.,* 2013). In the sagittal plane, the posture misalignment reviewed will entail changes to craniovertebral alignment, rounded shoulders, thoracic khypnosis, lumbar lordosis, anterior pelvic tilt, genu recurvatum presence. In the frontal plane postural misalignment review will include lateral head tilt, asymmetrical shoulder, elbow, hip, popliteal and medial malleoli heights. The method of digital camera imagery used to record posture has a reliability score of r=0.75 (Nam *et al.,* 2013). The digital camera imagery will involve the use of reflector markings to identified key anatomical landmarks, which will then be used to subsequently identify the aforementioned misaligned posture in the sagittal and frontal planes. These landmarks will also be used to measure CVA, CHA and SPA. The reliability score of the smartphone application to measure posture is r=0.71 and r=0.81 (Szucs & Brown, 2018; Boland *et al.*, 2016).

Craniovertebral Angle (CVA)

The participant's CVA will be measured according to Lau *et al.* (2009) protocol. The reliability of this protocol is r=0.86 (Lau *et al.*, 2009). Comparative analyses between unloaded and cranially loaded CVA will indicate the anterior translation of the cervical vertebrae in relation to the thoracic vertebrae due to the cranial load influence.

Craniohorizontal angle (CHA)

The participant's CHA will be measured according to Hazar *et al*. (2015) protocol, with a reliability score r=0.92. The comparative analyses of change in CHA will indicate the deviation of head on cervical vertebrae produced from the force imposed by the cranial load.

Standing Pelvic Angle (SPA)

The SPA will be measured according to the Kim *et al*. protocol (2009) protocol. The measurement will be recorded in the sagittal plane. An increase in the SPA is suggestive of anterior pelvic tilt during the loaded phase to accommodate the cranial load imposed on the vertebral column.

Navicular height

The participant's deviation in navicular tuberosity height will measured according to Starkey (2002) protocol. A decrease in navicular height during the loaded phase as compared to the unloaded phase is indicative of an adaptive measure to accommodate the force imposed by the cranial load.

Electromyography measures

Electromyography leads will be placed on the anterior and posterior surface areas of the cervical and lumbar muscles to determine change in voltage during the cranial loading and unloading phases. All EMG recordings will be normalized through a maximal isotonic neck extension and hip flexion. The EMG measures will quantify the change in muscle activity during cranial load weight bearing as compared to no load, thereby relating the extensor-flexor force relationship. Neurotrac Myoplus4 will used to measure muscle voltage changes.

STATISTICAL ANALYSIS

All data will be analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0 for windows (SPSS Inc, Chicago, IL, USA). Descriptive statistics will be presented as means, standard deviations, minimum and maximum values. Quantitative variables will be presented as percentages. T-tests and ANOVA will be employed to compare change in variables (postural angles, kinanthropometry, EMG voltage, pulmonary and proprioception measures) during the unloaded versus the cranial loaded phases. Pearson correlation tests will be used to measure the association between the changes in posture from unloaded to cranially loaded phases. A significance level will be set at $p \leq 0.05$.

DISCUSSION

Rural domestic manual labor has being an ongoing activity, which will persist in the future due to lack of financial resources and stereotypical perspective of community leaders (Kurten et al., 2020; Kurten et al., 2021a; Kurten et al., 2021b).Bucolic African men, women and children have different responsibilities in the family, which articulate within their larger community. Adult women are accountable for domestic activities such as cooking, cleaning and chaperoning children and the elderly (Potgieter et al., 2018). Pubescent and adolescent females are responsible for the transportation of food, water and firewood within and between neighboring communities (Mashiri, 1996). The most popular mode of transport in rural South Africa is walking because few families possess priceless transport technologies such as bicycles, wheelbarrows, animals and animal drawn carts and motorized vehicles (Kurten et al., 2020; Mashiri, 2007). Therefore, scientific investigations aimed at understanding the medical, physical, psychological, social and financial effects of rural live on its citizens needs to be undertaken to help improve the citizens' quality of life. The evidence gather of the impact of cranial loading on the posture of pubescent and adolescent females will the South African government awareness of the potential hazardous situation and help to find solution to prevent the ill effects. Therefore, phase one of the research community project to establish the status of the impact of cranial loading on young female South African porters' posture, kinanthropometry, cervical and lumbar muscle EMG activity, proprioception, pulmonary function and energy expenditure. Thereafter the phase two of research community project will progress to introduce exercise-strengthening programmes to improve muscle strength and endurance and alleviate neuro-musculoskeletal pain and injury. Physical therapy and Biokinetic rehabilitation exercise programmes to strengthen the porters' musculoskeletal system will help to stabilize the cervical and lumbar vertebrae preventing intervertebral disc compression and spondylolisthesis. The novel findings of the impact on head loading the porter's respiration and proprioception will increase the present body literature.

In phase two, the use of different cervical and lumbar orthotic devices will be introduced to determine whether these devices improve the porter's ability to transport cranial loads. Richard Benc an engineer designed a cervical brace to support female cervical vertebrae that habitually carried cranial loads (Robin, 2016). Benc referred to this cervical brace as the *halo head loading brace* (Robin, 2016). It was postulated that the biomechanical justification behind the cervical invention was to central distribute the external cranial load over the entire cervical vertebrae. It was hypothesized that central positioning of the external head load over the cervical vertebrae, will ensure whole surface area disc compression. This biomechanical design will entail that the entire the surface area of the superior vertebral disc centrum will rest over the entire inferior vertebral disc centrum (Motaung, 2021). By increasing contact surface area between the subsequent vertebrae, the caudal gravitational pull of the external cranial load/weight (force) will be uniformly distributed over the intervertebral disc, thereby reducing pressure, based on physical science equation that pressure is inversely proportional to area (Pressure = Force/Area) (Hall, 2015). Nevertheless, the ergonomic validity of the *halo head loading brace* needs to be empirical confirmed. This study aims to determine the reliability of this halo brace biomechanical postulation and pragmatic effect of reducing neuro-musculoskeletal pain and injury.

CONCLUSION

Cranial loading in rural communities in South Africa is strongly engrained in the cultural beliefs that many communities refuse to negate. As such the plight of the rural female South African is to carry loads on their heads persist producing numerous negative impacts on their health and wellbeing. Innovative engineering advance adapted cranial loading may provide a solution to diminish neuromuscular pain and discomfort. Further education of community leaders to allow females to use alternate mode of transport is greatly needed. The efficacy of the prescription of exercises to stabilize the vertebral column will be validated. The intention of the study is to improve the quality of life of rural community members.

REFERENCES

- Ando T, Piaggi P, Bogardus C, Krakoff J. (2019). VO_2max is associated with measures of energy expenditure in sedentary condition but does not predict weight change. Metabolism, 90:44-51. doi:10.1016/j.metabol.2018.10.012
- Boland, D., Neufeld, E., Ruddell, J., Dolezal, B., & Cooper, C. (2016). Inter- and intra-rater agreement of static posture analysis using a mobile application. Journal of Physical Therapy Science, 28(12), 3398-3402. doi: 10.1589/jpts.28.3398
- Echarri, J.J., & Forriol, F. (2002). Effect of axial load on the cervical spine: a study of Congolese woodbearers. International Orthopaedics, 26(3), 141-144. doi: 10.1007/s00264-002-0336-6
- Echarri, J., & Forriol, F. (2005). Influence of the type of load on the cervical spine: a study on Congolese bearers. The Spine Journal, 5(3), 291-296. doi: 10.1016/j.spinee.2004.09.010
- Ellapen, T., Abrahams, S., Desai, F., & Van Heerden, H. (2010). Impact of habitual cranial loading on the vertebral column of adolescent African females aged 12-15 years in the Deepdale region of Kwa-Zulu Natal. African Journal for Physical, Health Education, Recreation and Dance, 15(4). doi: 10.4314/ajpherd.v15i4.49555
- Gajdosik, R., Simpson, R., Smith, R., & DonTigny, R. (1985). Pelvic Tilt. Physical Therapy, 65(2), 169-174. doi: 10.1093/ptj/65.2.169

- Hall, S.J. (2015). *Basic Biomechanics* (7th ed.). McGraw-Hill Education, New York, USA
- Hande, D.N., Shinde, N., Khatri, S.M., Dangat, P. (2012). The Effect of Backpack on Cervical and Shoulder Posture in Male Students of Loni. International Journal of Health Science & Research, 2(3), 72-79. Retrieved from https://www.ijhsr.org/IJHSR_Vol.2_Issue.3_June2012/9.pdf
- Hassel, E., Stensvold, D., Halvorsen, T., Wisløff, U., Langhammer, A., & Steinshamn, S. (2015). Association between pulmonary function and peak oxygen uptake in elderly: the Generation 100 study. Respiratory Research, 16: 156. https://doi.org/10.1186/s12931-015-0317-0
- Hazar, Z., Karabicak, G., & Tiftikci, U. (2015). Reliability of photographic posture analysis of adolescents. Journal of Physical Therapy Science, 27(10), 3123-3126. doi: 10.1589/jpts.27.3123
- Kurten M, Motaung TG, Paul Y, Ellapen TJ (2020). Cranial loading: The plight of the rural South African female. Annuals of Physiotherapy & Occupational Therapy, 3(3). www.http://doi.10.23880/aphot-16000172
- Kurten M, Motaung GT, Ellapen TJ, Paul Y, Muluvhu TC, Barnard M, Hammill HV. (2021a). The effects of cranial loading among bucolic female African children neuro-musculoskeletal health and well-being: A literature overview (2000-2018) in "Physical Education and Sport for Children and Youth with Special Needs: Research - Best Practices – Situation". FIEP Publishers, Europe.
- Kurten M, Ellapen TJ, Paul Y. (2021). The impact of cranial loading on sagittal plane posture, kinanthropometry and muscle activity of South African female youth. Occupational Health of Southern Africa, 27(5):159-163.
- Lau, H., Chiu, T., & Lam, T. (2009). Clinical measurement of craniovertebral angle by electronic head posture instrument: A test of reliability and validity. Manual Therapy, 14(4), 363-368. doi: 10.1016/j.math.2008.05.004
- Lloyd, R., Parr, B., Davies, S., & Cooke, C. (2010a). No 'free ride' for African women: A comparison of head-loading versus back-loading among Xhosa women. South African Journal of Science, 106(3/4). doi: 10.4102/sajs.v106i3/4.153
- Lloyd, R., Parr, B., Davies, S., Partridge, T., & Cooke, C. (2010b). A comparison of the physiological consequences of head-loading and back-loading for African and European women. European Journal of Applied Physiology, 109(4), 607-616. doi: 10.1007/s00421-010-1395-9
- Lloyd, R., Hind, K., Parr, B., Davies, S., & Cooke, C. (2010c). The Extra Load Index as a method for comparing the relative economy of load carriage systems. Ergonomics, 53(12), 1500-1504. doi: 10.1080/00140139.2010.528454

- Mashiri M (1996) The relevance of non-motorised transport in the urban areas of South Africa. Contract Report CR–96/043. Pretoria: Department of Transport
- Mashiri M (1997) Sustainable transport: The case of nonmotorised transport in Southern Africa. Paper presented at the South African Transport Conference, September 1997, in Session 3C: Rural Accessibility and Transport.
- McArdle, W.D. Katch, F.I, Katch, V.L. (2010). Exercise Physiology: Nutrition, Energy and Exercise Performance. Lippincott Williams & Wilkins, New York, United States of America.
- McRoberts, L.B., Cloud, R.M., Black, C.M. (2013). Evaluating the New York Posture rating Chart for assessing changes in postural alignment in a garment study. Clothing and Textile Research Journal, 00(0): 1-16. DOI: 10.1177/0887302X13480558
- Motaung, T.G.S. (2021) .Pulmonary and Proprioceptive influence of habitual cranial loading porterage among female pubescents residing in the Glendale region of KwaZulu-Natal. Unpublished master's thesis. Tshwane University of Technology, Pretoria-West campus, South Africa.
- Nam, S., Son, S., Kwon, J., & Lee, N. (2013). The Intra- and Inter-rater Reliabilities of the Forward Head Posture Assessment of Normal Healthy Subjects. Journal of Physical Therapy Science, 25(6), 737-739. doi: 10.1589/jpts.25.737
- Prentice W.E. 2011. Rehabilitation techniques for Sports Medicine and Athletic Training (5th Ed.).
- Porter, G., Hampshire, K., Abane, A., Munthali, A., Robson, E., & Mashiri, M. et al. (2012). Child Porterage and Africa's Transport Gap: Evidence from Ghana, Malawi and South Africa. World Development, 40(10), 2136-2154. doi: 10.1016/j.worlddev.2012.05.004
- Porter, G., Hampshire, K., Dunn, C., Hall, R., Levesley, M., & Burton, K. et al. (2013). Health impacts of pedestrian head-loading: A review of the evidence with particular reference to women and children in sub-Saharan Africa. Social Science & Medicine, 88, 90-97. doi: 10.1016/j.socscimed.2013.04.010
- Potgieter CA, Pillay R, Rama S (2018) Development and Transport in rural Eastern Cape in South Africa. pp: 56. 2.
- Robin, A. (2016). The Head Loading Halo Facilitates Ergonomic Transportation of Water. Arts and Design.
- Starkey, R. (2002). Evaluation of Orthopeadic and Athletic injuries (2nd Ed.). FA Davis Company, Philadelphia, United States of America.

- Stewart, A., Marfell-Jones, M., Olds, T. & De Ridder, H. (2011). International standards for anthropometric assessment. Lower Hutt: New Zealand.
- Szucs, K., & Brown, E. (2018). Rater reliability and construct validity of a mobile application for posture analysis. Journal of Physical Therapy Science, 30(1), 31-36. doi: 10.1589/jpts.30.31
- Susta, D., Minetti, A.E., Moia, C., Feretti, G. (2000). Energy cost of walking and running uphill and downhill at extreme slopes. *European Journal of Physiology*, 440(5): R36-R36.