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Review

Dual energy X-ray absorptiometry positioning protocols in assessing body composition: A systematic review of the literature

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ABSTRACT

Objectives: To systematically identify and assess methods and protocols used to reduce technical and biological errors in published studies that have investigated reliability of dual energy X-ray absorptiometry (DXA) for assessing body composition.
Design: Systematic review.
Methods: Systematic searches of five databases were used to identify studies of DXA reliability. Two independent reviewers used a modified critical appraisal tool to assess their methodological quality. Data was extracted and synthesised using a level of evidence approach. Further analysis was then undertaken of methods used to decrease DXA errors (technical and biological) and so enhance DXA reliability.
Results: Twelve studies met eligibility criteria. Four of the articles were deemed high quality. Quality articles considered biological and technical errors when preparing participants for DXA scanning. The Nana positioning protocol was assessed to have a strong level of evidence. The studies providing this evidence indicated very high test–retest reliability (ICC 0.90–1.00 or less than 1% change in mean) of the Nana positioning protocol. The National Health and Nutrition Examination Survey (NHANES) positioning protocol was deemed to have a moderate level of evidence due to lack of high quality studies. However, the available studies found the NHANES positioning protocol had very high test–retest reliability. Evidence is limited and reported reliability has varied in papers where no specific positioning protocol was used or reported.
Conclusions: Due to the strong level of evidence of excellent test–retest reliability that supports use of the Nana positioning protocol, it is recommended as the first choice for clinicians when using DXA to assess body composition.

1. Introduction

Dual-energy X-ray absorptiometry (DXA) is a widely accepted method for the assessment of tissue composition.[1] Low bone mineral density (BMD) and associated conditions such as osteoporosis and osteopenia constitute a significant health problem that costs over eight hundred and thirty million dollars annually and osteoporosis is a significant cause of morbidity and mortality.[2,3] The need to accurately and effectively measure BMD in conditions such as osteoporosis led to the development of the DXA scanner.[4] Now, DXA is considered the gold standard for the assessment of BMD and associated fracture risk.[5] However, DXA is also a valuable clinical tool in the assessment of body composition (BC), due particularly to its ability to assess body segments for lean mass (LM) and fat mass (FM) distributions.[6] The absorption rates of the two different energy levels (40 and 70 KeV) within DXA coupled with the distinctive elements of bone, fat, and lean tissue enable clear imaging of each tissue type and subsequent analysis.[6] Therefore, DXA can be used for assessing segmental body composition (SBC) and is currently used in clinical, sporting and research settings. The data gathered from SBC scans have improved knowledge of malnutrition, growth, aging, obesity and the efficacy of medical treatment interventions (surgical, pharmacological, dietary and exercise).[7] When used in the sport setting, DXA has enabled the tracking of players overall tissue composition as it has been found that individuals with the lowest start of season BMD and LM values have a greater occurrence of bone related injuries.[8] Nevertheless, the

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reliability of the DXA scanner is fundamental to the validity of all clinical investigations and research studies that use it to assess BC.

In order to draw valid and reliable conclusions from DXA scan results, the concept of error must be considered. The literature describes biological and technical error as sources for reduced test–retest reliability of the DXA scanner.[9] The International Society for Clinical Densitometry recommends precise measures during preparation of the participant (fasting state, clothing, time of day, physical activity and empty bladder) and consistent positioning.[9] It has been shown that sources of biological error in DXA results include hydration,[1,9,10] stomach content and food consumption,[1,9,10] time of day of scanning[9] and physical activity[9,10]; furthermore sources of technical error include artefacts such as clothing,[9] number of operators used to complete scans[11] and position of participant.[1,9,12,13]

The influence of positioning of the participant on the DXA scanner can be analysed further by considering three identifiable positioning protocols. The first of these is the National Centre for Health Statistics, National Health and Nutrition Examination Survey (NHANES) Body Composition[12] positioning protocol, which the International Society for Clinical Densitometry recommends.[9] The NHANES protocol requires individuals to assume a supine position with feet secured together with a strap, and the palms of the hands flat on the scanning table and not touching the lateral aspect of the body. It should be noted that the Australian and New Zealand Bone Mineral Society (ANZBMS)[14] employs the same body position. The second key protocol, the Nana positioning protocol,[1] requires individuals to be in a supine position while placing hands in a neutral position alongside the body and feet in radio-opaque positioning pads. The third approach evident in the literature involves no specific positioning protocol being reported at all.

The study of Kerr et al.[13] is to date the only study that has attempted to compare the reliability of different DXA positioning protocols for assessing BC, to identify which protocol was the most valid and reliable to use in clinical practice. They reported the Nana positioning protocol was the preferred positioning protocol based upon participant comfort when assessing BC with DXA. In their study, the positioning protocols were modified versions of the standard Nana and NHANES protocols. In contrast, most other studies that have assessed the test–retest reliability of their DXA scanner have not compared the reliability of different positioning protocols.

Therefore, the aim of this literature review was to systematically identify and assess methods and protocols used in previously published research that has investigated reliability of DXA, when it is employed to assess BC, to reduce technical and biological errors.

2. Methods

A search of academic databases was undertaken on 26.09.2016 with the intention of finding studies that have assessed the test–retest reliability of positioning protocols used when assessing BC by DXA. The search was limited to studies conducted over the recent 10-year period (01.09.2006–26.09.2016) to maintain currency. The search was limited to only articles that included the term 'DXA' or a synonym for DXA in the title, as searches not limited in this way provided an excessive number of irrelevant articles. Details of the search strategy and key terms can be found in Fig. 1.

Two reviewers (F.S and C.P) assessed the identified literature and removed duplicates. Titles and abstracts were initially screened and articles removed if eligibility criteria were not met. Inclusion criteria included: (1) studies conducted on living human participants, (2) studies of an adult population, and (3) studies primarily investigating reliability of DXA scanning protocols. Exclusion criteria were: (1) non-healthy subjects (e.g. subjects with: osteoporosis, current fractures, hemiarthoplasty and total joint replacements, rheumatoid or osteoarthritis, current cardiac or pulmonary conditions, or diabetes) (2) studies published prior to September 2006, (3) studies comparing MRI or CT to DXA, and (4) studies not available in English. In the event that insufficient details were provided in the titles and abstracts of articles to allow determination of eligibility, review of full texts was completed, with reference to eligibility criteria and ineligible articles were removed. The remaining articles were included in this literature review. A PRISMA flow diagram (Fig. 1) was used to document the study screening and article selection processes.[15]

In order to critically appraise the included DXA reliability full text articles, a modified version of the reliability and validity critical appraisal tool (CAT) described by Brink and Louw[16] was utilised, with items designed to appraise studies of validity removed, since the focus of this review was studies of reliability. The thirteen-item CAT was reduced to ten items by removing all items that did not relate to reliability, and was applied by two independent reviewers (F.S and C.P) in order to assess the methodological quality of each study. When both assessors were not in agreement, a consensus was reached by discussion to determine the item's final CAT results. The CAT did not originally include a scoring system; therefore for the purpose of this literature review, a scoring system was implemented to aid in a quality and reliable analysis, similar to previously published reviews.[17–20] Studies of higher quality scored ≥60% in the modified CAT, and were rated higher due to their superior methodology.[21]

To receive a positive appraisal regarding the appropriateness of statistics in the CAT, each study reporting reliability must have reported an intraclass correlation coefficient (ICC) accompanied with confidence intervals (CI) or a percentage change in mean accompanied with typical error of measurement.[22] If the only basis for inclusion of a study was that it reported a percentage change in mean, then the calculation of the percentage change in mean must have complied with the guidance of previous work and have included a typical error of measurement in calculations.[23,24] Pearson correlation coefficients were not deemed suitable as measures of reliability; as they did not take into account the consistency of measurements from test to retest and the change in average measurements of participants.[25] The ICC results of the studies that included ICC values were interpreted as indicators of reliability as follows: ICC of 0.00–0.29, very low reliability; 0.30–0.49, low reliability; 0.50–0.69, moderate reliability; 0.70–0.89, high reliability; and 0.90–1.00, very high reliability.[26] An assessment of high or very high reliability depended primarily upon a reported high or very high ICC (above 0.70) or a low reported percentage change in the mean. When used the reported change in mean needed to be lower than the minimum clinically significant difference ascertained through consultation with practitioners. This ensured that any systematic error in repeated measurements observed during reliability testing was not sufficiently large to obscure clinically important changes or differences in the respective outcome measure — another indication of reliability. Unfortunately, only three studies in this review reported minimum clinically significant differences and therefore this statistic could not be used to compare studies.

Following critical appraisal, data were extracted from the included full text articles and tabulated to identify participant characteristics, the extent of standardisation employed to minimise technical and biological errors, the types of statistical analyses undertaken, and reported results of each study.

A meta-analysis was not undertaken due to the diversity of the methods examined and the statistical analyses employed. Rather, a critical narrative approach was applied to synthesise and analyse the data obtained from the included studies, using a level of evidence approach.[27] Each positioning protocol identified from included studies was assigned a 'strong', 'moderate', or 'limited'

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