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Precision of shoulder anatomical landmark calibration by two approaches: A CAST-like protocol and a new anatomical palpator method

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ABSTRACT

The objective of the study was to compare the precision of shoulder anatomical landmark palpation using a CAST-like method and a newly developed anatomical palpator device (called A-Palp) using the forefinger pulp directly. The repeated-measures experimental design included four examiners that twice repeated measurements on eleven scapula and humerus anatomical landmarks during two sessions. Inter-session and inter-examiner precision was determined on volunteers. A-Palp accuracy was obtained from in vitro measurements and using virtual palpation on 3D bone models. Error propagation on the motion representation was also analyzed for a continuous motion of abduction movement performed in the shoulder joint. Palpation results showed that CAST and A-Palp methods lead to similar precision with the Maximal A-Palp calibration error being 1.5 mm. In vivo precision of the CAST and A-Palp methods varied between 4 mm (inter-session) and 8 mm (inter-examiner). Mean propagation of the palpation error on the motion graph representation was 2° and 5° for scapula and humerus, respectively. A-Palp accuracy was 3.6 and 8.1 mm for scapula and humerus, respectively. The A-Palp seems promising and could probably become an additional method next to today's marker-based motion analysis systems (i.e., Helen–Hayes configuration, CAST method).

1. Introduction

Spatial location of anatomical landmarks (ALs) is often required to quantify various aspects of skeletal morphology. Such location can be usually performed using two protocols. Manual palpation allows AL location using finger-tips and may be combined with three-dimensional (3D) digitizing [1]. Virtual palpation uses 3D computer models (e.g., obtained from computerized tomography (CT)) [1]. These two palpation protocols can be used independently. Manual palpation alone is used in clinical activities for various aims (e.g., identification of painful areas, positioning of electrodes, morphological measurements). Virtual palpation alone is useful to quantify morphological parameters from medical imaging (e.g., limb orientation, vicious joint angle) Combining data from both manual and virtual palpation protocols allows achieving supplementary analysis: for example, registration protocols aiming at building reference frames for motion representation and musculoskeletal analysis [1].

Inaccuracy in AL selection leads to discrepancies in the interpretation of the data regardless of the quality of the hardware used for measurements [2]. Use of standardized definitions for AL location during the above activities allows for a better result comparison and data exchange [2]; this is a key element for patient follow-up, or the elaboration of quality clinical and research databases. Such definitions have been recently proposed [3] and complete the recommendations proposed by the International Society of Biomechanics to define joint technical frames [4–6]. Such standardization effort is also of importance to improve the customization of current modeling systems [7].

This paper aimed to determine if the precision (i.e., repeatability) and accuracy of manual palpation procedures of shoulder ALs could be improved during motion analysis. The latter analysis requests spatial coordinates of particular ALs to build local technical frames and to represent motion data according to clinical conventions [8,9]. It has been already mentioned that the repeatability of such measurements is sensitive to the quality of the AL location [2]. Two protocols are usually reported in the literature to locate and to track AL trajectories during in vivo

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digitized by one examiner only using the Pronk's palpator [21], showed a palpation error of about 2.5° [22].

Motion representation cross-talk was already reported previously for the knee [20]. In this study, cross-talk was found for the humerothoracic associated components (Fig. 3), and underlined the sensitivity of marker placement on long bones with only two spatially adjacent ALs (i.e., ME and LE) used in the anatomical frame definition.

The main drawback of the A-Palp method, compared to CAST, is maintaining the rigidity of the palpating device between the finger palpation calibration step (Fig. 1C) and the AL digitizing (Fig. 1D). This is currently solved by strapping the palpating finger into a customized thermoplastic mould. Applied over a long duration, a strapping which is too tight can lead to a decrease of the finger blood supply, and to a loss of pulp sensitivity. Ergonomic improvement of the gauntlet should probably solve that drawback. Another disadvantage, like other methods based on marker cluster to track segment trajectories, is the shape of the cluster and soft tissue artifacts [8,9]. Artifact minimization can be obtained, similar to this study, using cluster configuration including four markers [13,11,23] to permit further data optimization [24].

Although the CAST and A-Palp methods lead to similar results when performed by well-trained users, it must be emphasized that the latter method seems advantageous. Indeed, it allows a more natural palpation since the finger pulp must not leave the currently palpated AL surface prior to digitizing. A-Palp is also less cumbersome because it does not require a supplementary instrument like the CAST stick. Palpated subjects seem to consider the A-Palp finger pulp as less threatening and intimidating then being touched by a stick tip. This is a sensitive argument when dealing with patient palpation. The same method should also be more easily usable when ALs are hidden in soft tissue folds (e.g., palpation with obese subjects). A-Palp also allows faster AL digitizing because the AL spatial coordinates can be digitized directly with the palpating finger still in place. The A-Palp method is relatively time-effective. Pre-calibration of calibration plate and palpation gauntlet (see Fig. 1, steps 1 and 2) must occur only once, and was performed in this study several weeks before the data collection. Finger pulp calibration must occur each time the gauntlet is mounted on the palpating finger (i.e., just before the palpation of the subject). Like CAST, AL calibration is performed for each subject's palpated AL. Data processing can be integrated into a software interface for semi-automated procedures. Current software implementation of the method allowed semi-automated processing of all data collected during each motion analysis session (see Fig. 1, steps 3 and 4) thanks to a batch system using file scripts. The whole procedure, from data collection (i.e., steps 3 and 4 performed on 11 ALs and motion data) to data processing procedures (including AL registration to motion, building of anatomical frames and generation of motion graphs) took less than 45 min in this study.

5. Conclusion

Results showed that the A-Palp method is as robust as CAST-based protocol when performed by well-trained examiners. A-Palp has the advantage of using the examiner's finger pulp directly for AL digitizing without interposition of a stick or probe. Finger-tip palpation is therefore more natural for the examiner and less intimidating for the patient. The A-Palp method is promising and is currently used to build of a reference database including shoulder complex movements. It could probably become an additional method next to today's marker-based motion analysis systems (i.e., Helen–Hayes configuration, CAST method).

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Conflict of interest

The authors have no conflicts of interest to declare.

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