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Short communication

An innovative solution to reduce muscle deformation during ultrasonography data collection

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ABSTRACT

Background: 3D freehand ultrasound enables the creation of volumetric data. The acquisition of morphological features, such as muscle volume, is influenced by the variations in force applied to the skin with the ultrasound probe. To minimise the deformations, a concave-shaped plastic mount combined with a custom-shaped gel pad was developed for the ultrasound head, named Portico. This study analyses to what extent the Portico reduces muscle deformation and corresponding errors in estimating muscle volume.

Method: Twenty medial gastrocnemius (MG) muscles were assessed (10 from typically developing children; 10 from children with spastic cerebral palsy). Two repetitions were acquired in each of the following approaches: (1) with the lower leg submerged in a water tank as a non-deformed reference; (2) probe-on-skin (PoS) as the conventional approach and (3) the newly introduced Portico. PoS and Portico data were registered with respect to the ones corresponding in a water tank. An in-house software package (Py3DFreeHandUS) was used to process the data and MG volume was estimated using MeVisLab. The minimal detectable change (MDC) was calculated.

Results: With respect to the PoS approach, the Portico reduced muscle deformation by 46%. For both the typically developing and spastic cerebral palsy cohorts, lower MDCs were found when using the Portico.

Discussion: Despite the improvements, the Portico did not yield statistically more reliable MG volume estimations than the traditional PoS approach. Further improvement can be attained by optimising the fit between the gel pad and the curvature of the limb, using a larger choice of Portico geometries.

1. Introduction

Estimating muscle volume is useful for clinical decision-making. Magnetic-resonance imaging is considered the golden standard, but it is not always suitable for younger children. An alternative is 3D freehand ultrasound (3DfUS), where the pose of the ultrasound (US) probe is tracked whilst images are recorded (Cenni et al., 2016a; Gee et al., 2004; Lasso et al., 2014). 3DfUS requires shorter measurement time, is more child-friendly, and has already been used to assess morphological alterations in children with spastic cerebral palsy (SCP) (Barber et al., 2016; Fry et al., 2004; Haberfehlner et al., 2016).

In 3DfUS, the calculation of morphological features, such as muscle volume, is influenced by variations in the force applied to the skin with the US probe (Barber et al., 2009; Raiteri et al., 2016). Some force is necessary to achieve full contact between the linear US probe and the curvature of the leg (Fig. 1), permitting full visualisation of the anatomy within the US image. However, this force may deform subcutaneous tissues and muscles in different directions. This was avoided in a 3DfUS validation analysis on the medial gastrocnemius (MG), performed by submerging the leg in a water tank (WT). This yielded a minimal detectable change (MDC) for volume estimations of approximately 2% (Barber et al., 2009), however the use of a WT requires a cumbersome and time consuming procedure.

Routine investigations are instead carried out using the US probe-on-skin (PoS) approach. This requires copious amounts of gel to reduce the deformation (Weide et al., 2015), as well as an experienced operator. A preliminary analysis for estimating MG

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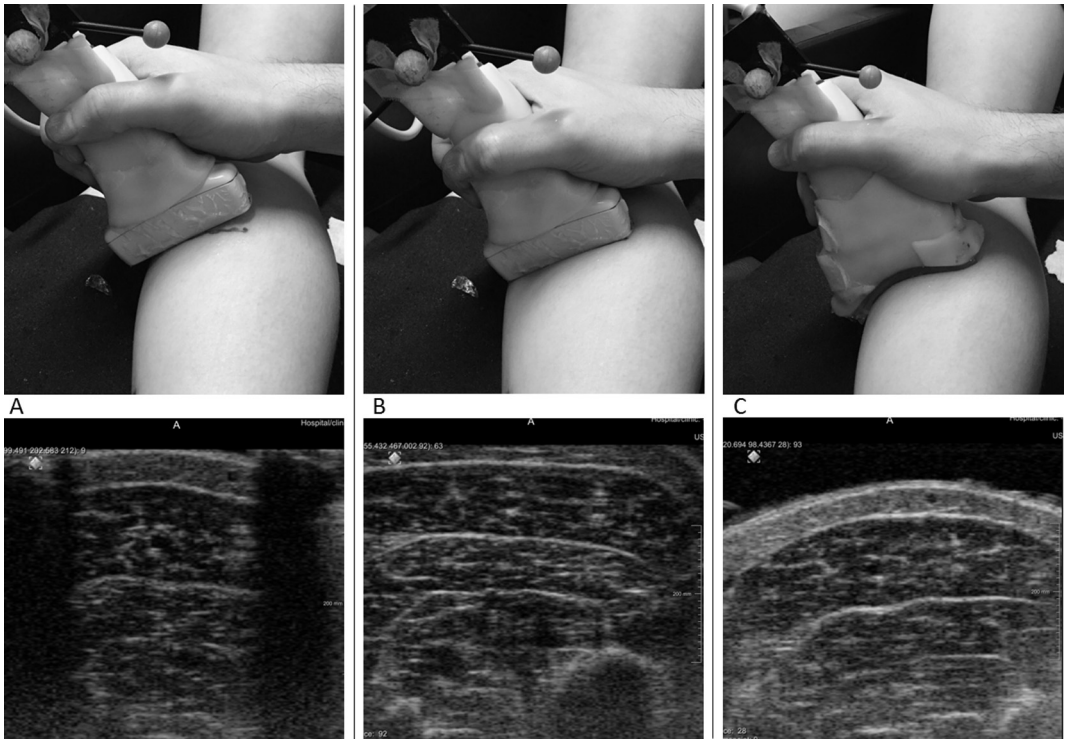

Fig. 1. The top row consists of photos of an acquisition using an US probe and the bottom row consists of the resulting US images. The acquisitions are taken in different conditions: (A) acquisition without applied force, (B) acquisition applying the force required to enable full contact between probe and leg, (C) acquisition using the Portico device.

volume using the PoS approach revealed an MDC of approximately 10% (Cenni et al., 2016b). This is small enough to distinguish between children with SCP and their typical developing (TD) peers, according to a previously reported smallest difference of 19% (Barrett and Lichtwark, 2010). However, for longitudinal studies, the expected differences can be lower than 10% (Williams et al., 2013), suggesting that the MDC for estimating MG volume should be further reduced.

An additional reason to minimise deformation is when a muscles width is wider than the probe, or when several neighbouring muscles are recorded in an acquisition. This requires a combination of multiple US sweeps, where proper matching of the anatomical features is critical. An inconsistent magnitude and direction of applied force can deform the features, resulting in poor sweep alignment. Consequently, this would introduce errors in the muscle volume estimations.

To minimise deformations and reduce the required acquisition effort, an innovative solution was conceived. A concave-shaped plastic mount named 'Portico' was developed for the US probe head, containing a compartment for the insertion of a custom-shaped gel pad (Fig. 2). This provides a more ergonomic fit to the natural curvature of the lower leg, reducing pressure on a leg with pronounced curvature, and avoiding the need to submerge the leg in a WT.

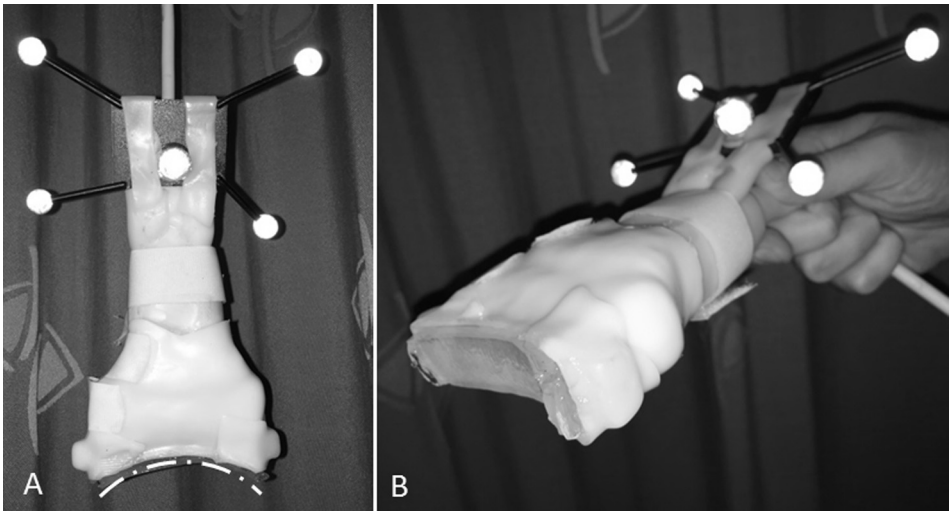

Fig. 2. (A) The probe with the Portico mounted and (B) the Portico with the custom cut gel pad inserted. A cluster of reflective markers rigidly affixed to the probe is also visible.

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