Ultrasound in Med. & Biol., Vol. 41, No. 9, pp. 2275–2283, 2015

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2015.04.027

● *Review*

APPLICATION OF ULTRASONOGRAPHY IN THE ASSESSMENT OF SKELETAL MUSCLES IN CHILDREN WITH AND WITHOUT NEUROMUSCULAR DISORDERS: A SYSTEMATIC REVIEW

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(*Received* 6 *October* 2014; *revised* 3 *March* 2015; *in final form* 30 *April* 2015)

Abstract—The purpose of this study was to systematically review published studies (2000–2014) carried out on the application of ultrasonography (US) to evaluation of skeletal muscle size in children with and without neuromuscular disorders. Different databases including PubMed, Science Direct, OVID, MEDLINE, CINAHL, EMBASE, ProQuest and Google Scholar were searched. The key words used were: "children," "ultrasound," "skeletal muscles," "neuromuscular disease," "neurogenic disorders," "spina bifida," "myelomeningocele" and "reliability." Eighteen articles were found to be relevant. Eight studies applied US in combination with additional methods of assessment. Four of the 18 studies did not have a control group. Ten studies applied only US in the assessment of skeletal muscles in children with and without neuromuscular diseases. In 9 studies, there were children ranging widely in age, and in 3 studies US was used to determine normal values for skeletal muscles. According to the results of these 18 reviewed articles, US is an appropriate, reliable and highly predictive method for assessment of skeletal muscles in children. (E-mail: Mohseni_bandpei@yahoo.com) © **2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Children, Myelomeningocele, Neuromuscular disease, Reliability, Skeletal muscles, Spina bifida, Ultrasound, Systematic, Review.**

INTRODUCTION

Neuromuscular diseases may cause structural muscle changes, including muscle atrophy or pseudo-hypertrophy through fatty and connective tissue infiltration (Heckmatt et al. 1982; Reimers K et al. 1993b). It was reported that muscle size and cross-sectional area can be used as an index to determine the disruption in muscle architecture caused by neuromuscular diseases in children (Heckmatt et al. 1988a, 1988b; Kamala et al. 1985; Lamminen et al. 1988; Pillen et al. 2003; Schmidt and Voit 1993; Zuberi et al. 1999) and adults (Maurits et al. 2003; Reimers K et al. 1993b). Different imaging techniques such as magnetic resonance imaging (MRI) (Lovitt et al. 2004; Morakkabati-Spitz et al. 2006), computed tomography (CT) (Schedel et al. 1992) and ultrasonography (US) (Brockmann et al. 2007; Van der Hoeven 2003) are available to evaluate muscle size and shape and also to detect muscle pathology and its progression. Among these techniques, US has been reported to be a tolerable, useful, non-invasive and easily accessible method for assessment of muscles without the ionizing radiation in adults (Kamala et al. 1985; Lamminen et al. 1988; Maurits et al. 2003; Pillen et al. 2003; Schmidt and Voit 1993; Zuberi et al. 1999).

Many studies have indicated that muscles changes can be reliably visualized using US in healthy patients and patients with musculoskeletal disorders in the adult population (Ghamkhar et al. 2011; Javanshir et al. 2010; Mohseni-Bandpei et al. 2014a). Ghamkhar et al. (2011), in a systematic review, investigated the reliability

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and validity of US in the assessment of spinal stabilizer muscles in patients with low back pain. They concluded that US is a reliable method for assessment of spinal muscles.

Since 1980, US has been used to detect skeletal muscle pathology and determine the severity of disease in patients with all types of neuromuscular disorders (Heckmatt et al. 1980). These changes can be determined by muscle histology, the results of which have been reported to be correlated with US measurements in many studies (Brockmann et al. 2007; Heckmatt et al. 1989; Maurits et al. 2003, 2004). Normal muscles appear as low echo-intensity structures; increased muscle echo intensity is indicative of a neuromuscular disorder (Pillen et al. 2008). Previous studies had indicated that fat and fibrous tissues are responsible for the high echo intensity appearance of muscles (Pillen et al. 2009; Reimers CD et al. 1993a; Reimers K et al. 1993b).

Many studies have investigated skeletal muscles thickness and echo intensity in patients with neuromuscular disorders using US or US synchronized with electromyography (EMG) or visual assessment (*e.g.,* Aydinli et al. 2003; Brockmann et al. 2007; Mohseni-Bandpei et al. 2014b; Van Rohden et al. 1990). As EMG is an invasive method and is not tolerated by children, the non-invasiveness of US makes it especially appropriate for the assessment of skeletal muscles in this population (Brockmann et al. 2007).

Different conclusions have been drawn in previous studies in which US was used to assess muscles changes in children with neuromuscular disorders. There is still a lack of general consensus on the usefulness of US in the evaluation of muscle abnormalities in children. The purpose of this study was to systematically review published studies (2000–2014) carried out on the use of US for evaluation of skeletal muscle thickness in healthy children and children suspected of having neuromuscular disorders.

METHODS

This systematic review was performed according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Liberati et al. 2009).

Search strategy

Different available databases were searched to find studies on the use of US in the assessment of skeletal muscle changes in children for the period 2000–2014. The databases searched were PubMed (Public/Publisher Medline), Science Direct, OVID (OffshoreVessel Inspection Database), MEDLINE (Medical Literature and Retrieval System Online), CINAHL (Cumulative Index to Nursing and Allied Health Literature), EMBASE (Excerpta Medica Database), ProQuest and Google Scholar. The time frame 2000–2014 was chosen because most studies conducted before 2000 were not accessible in full text and some suffered from methodologic flaws. The search strategy was carried out according to PRISMA (Fig. 1). The following key words were used: "children," "ultrasound," "skeletal muscles," "neuromuscular disease," "neurogenic disorders," "spina bifida," "myelomeningocele" and "reliability." Furthermore, the references provided at the end of eligible studies were also searched.

Study selection

Inclusion criteria. To be included in this review, studies had to involve investigation of US in the evaluation of skeletal muscles, use of US in children, or US evaluation of skeletal muscles in healthy children or children suspected of having neuromuscular diseases and had to be published in English.

Exclusion criteria. Studies in which US was applied in the assessment of skeletal muscles in adults and studies not published in English were excluded. Abstracts of studies published in conference or seminar proceedings were also excluded from this review.

Data extraction and methodological quality

After a search of the available databases using the aforementioned key words, 325 articles were found. Two reviewers (N.R. and I.A.) independently selected the relevant studies from different databases for review. A discussion panel was held to form a consensus on disagreements. Some studies were excluded on the basis of their titles and abstracts. If a decision to include the study could not be made on the basis of the title or abstract, the

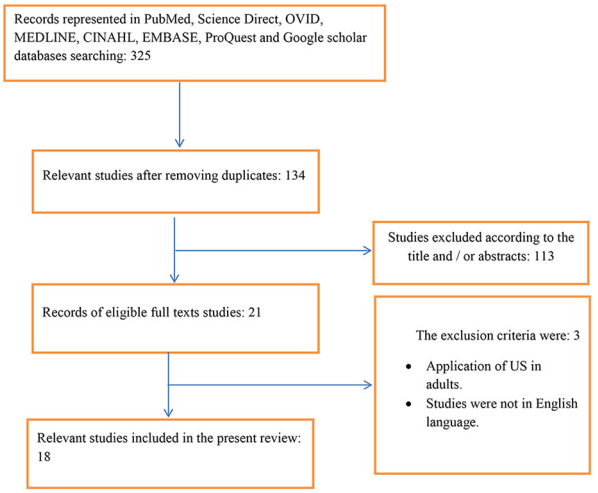

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart of study selection process.