Student perceptions of novel and traditional anatomy teaching tools in sport and exercise science

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SUMMARY

Anatomy teaching is considered a cornerstone of Sport and Exercise Science programmes, however has a wide array of teaching tools to consider. The present study has compared student perceptions of traditional anatomy teaching tools (cadaveric prosections, plastic models, electronic resources and printed resources) and novel teaching tools (ultrasound, muscle elastics and muscle modelling). 28 students from a Sport and Exercise Science cohort completed a student perception of anatomy teaching tools questionnaire. Students ranked cadaveric prosections, muscle modelling and muscle elastics as their top 3 tools, while cadaveric prosections were consistently rated significantly higher than printed resources and plastic models in students' perception of achieving learning outcomes (P<.05). Students reported difficulties in identifying anatomical structures with ultrasound. However, 70% recommended ultrasound for teaching, along with 67% and 86% for novel methods of muscle elastics and muscle modelling, respectively. The present study has demonstrated high student perceptions of cadaveric prosections for anatomy teaching. However, it notes that this is not a viable option for all higher education institutions. Muscle modelling appears as a novel method that is well perceived by students; however, educators should continually engage with students in relation to the most effective teaching tools.

Key words: Teaching – Ultrasound – Prosections – Modelling – Sport and exercise science

INTRODUCTION

The teaching of anatomy is a cornerstone within Sport and Exercise Science (SES), with applications to physiology, biomechanics, rehabilitation and sports medicine (Anderton et al., 2016). Historically, anatomical resources include cadaveric study, schematic diagrams, painted models and histological slides (McLachlan and Patten, 2006, Patra et al., 2022). Despite variation in anatomical objectives across the higher education sector, a shared aim of gross human anatomy is deciphering the relationship between structures, a skill which translates into clinical, sporting and wider professional fields (Chapman et al., 2013).

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In anatomical teaching, spatial awareness refers to the ability to perceive, identify and mentally manipulate structures within the human body. It involves three-dimensional (3D) visualisation of multiple systems, even when they are not directly visible. The development of this skill requires a large range of input stimuli (Silén et al., 2022) and, by extension, variation in teaching and learning resources. Cadaveric dissection has historically been considered the 'gold-standard' for anatomical education (Williams et al., 2014), acting as an 'active' and '3D' teaching tool (Smith et al., 2022). A fundamental objective within musculoskeletal (MSK) modules is to appreciate functionality that occurs across three-planes of motion. In comparison to the isolated muscular movements identified in traditional table textbooks, cadaveric dissection and prosections provide opportunities to simulate movement and observe structural relationships (Pather, 2015). However, its use has become limited in higher education institutions due to the signficant maintentance and care costs (Sugand et al., 2010). Anatomy teaching tools now readily include 3D applications and virtual reality – programs which aim to develop users' constructive memory outside of cadaveric settings, (Chan and Cheng, 2011, Richardson et al., 2021, Mitchell and Batty, 2009, Fitzgerald, 1992, Abdullah et al., 2021). Whether the input stimulus contains cadaveric dissection or 3D applications, the multisensory active learning tasks used alongside are key for enhancing visual and spatial memory (Quak et al., 2015).

At present, reviews of anatomy teaching resources have primarily focused on delivery to medicine and health science programmes (Richardson et al., 2021, Mitchell and Batty, 2009, Fitzgerald, 1992, Abdullah et al., 2021) directed towards cadaveric prosections and 3D learning technologies (Peeler et al., 2018, Rodríguez-López et al., 2020), with the outcome measures being specific to stu-

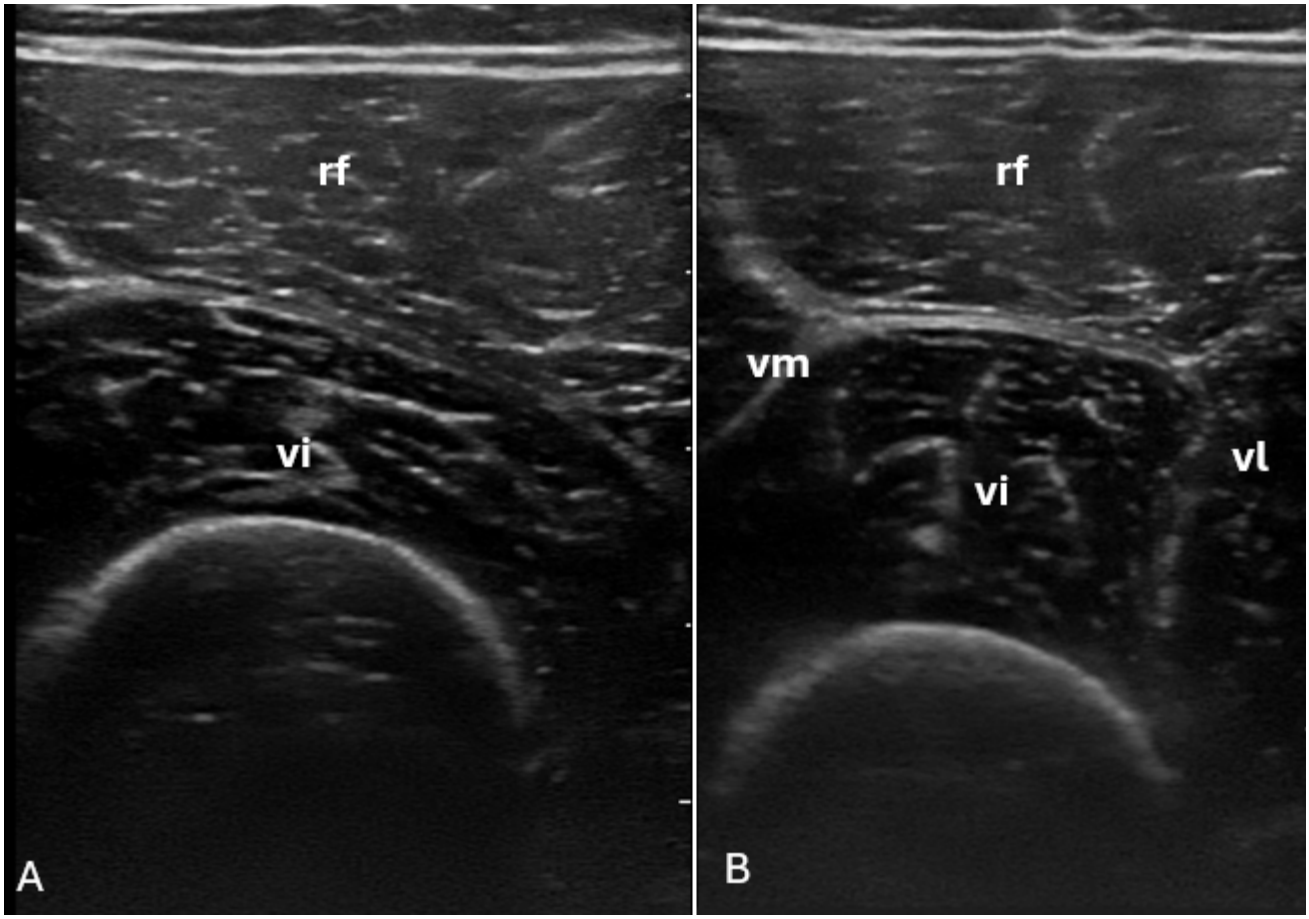

Fig. 1.- Still frames from a dynamic quadriceps extension moment captured by ultrasound of Dynamic ultrasound allows the user to observe real-time cross-sectional changes of muscles to aid understanding of agonistic mechanisms. **A)** cross-sectional relaxed and **B)** contracted, is used to demonstrate the living anatomy of the region including relationship of structures to bone, aponeuroses and vessels. RF = rectus femoris, VM = vastus medialis, VI vastus intermedius, VL = vastus lateralis.

dents and conflicting within literature (Hariri et al., 2004, Lisk et al., 2015). There are minimal evidence of haptic-spatial pedagogical opportunities specifically used within SES cohorts and for objectives associated with the functionality of the MSK system. As a result, the present study aims to evaluate three relatively novel active learning tools that can be used to achieve functional anatomical objectives, namely, 1) Ultrasound, 2) Muscle Elastics (ME), and 3) Muscle Modelling.

Novel Anatomy Teaching Tools

Ultrasound

Ultrasound provides the learner with a presence of "Living Anatomy" through active exploration (Dreher et al., 2014) and is increasingly used as a first line of investigation within the clinic (Fig. 1). Ultrasound has received mixed results regarding anatomical understanding, with some students reporting increased confidence and knowledge of spatial relationships and anatomical variations (Dilley and Smith, 2015, Swamy and Searle, 2012, Sweetman et al., 2013). Similarly, within a bioscience cohort, 93% of students (n = 107) perceived an improvement in anatomical understanding, 94% noted an improvement in identifying clinical relevance, with 95% recommended that ultrasound should be integrated into the anatomical curriculum (Edwards et al., 2023). Despite session enjoyment being important for the learning environment, it remains less conclusive whether ultrasound aids student understanding or learning of anatomy amongst medical students, with mixed results reported (Dreher et al., 2014, Kondrashov et al., 2015, Chen et al., 2022, Edwards et al., 2023). Furthermore, the relevance and effectiveness of this teaching tool amongst SES students remains unreported in extant literature.

Fig. 2.- Students attach the elastics to the skeletal attachment sites thereby generating a muscle force line using prosections and 3D Models as reference points.

Muscle Elastics

Muscle Elastics is a novel teaching technique, which has been developed in relation to muscle force lines, an important concept used for identifying function due to stress and contact force (Kim et al., 2009). Students actively 'attach' an elastic (the muscle) to a skeleton counterpart, paying attention to osseus attachments, fascicular orientation and interaction with aponeuroses (see Fig. 2), as noted by the prosections and in-house 3D force-line models developed by anatomical staff. Learners can effectively 'pull' on the elastic to aid simulation of the muscle function in relation to the joint centre of rotation. Specifically, they can develop a tool which can be manipulated into sporting scenarios and generates discussion around synergistic, antagonistic and compensatory muscles. To date, there is a lack of literature within the field describing such a technique used in undergraduate education, either with medical students or SES cohorts.

Muscle Modelling

Muscle modelling is an expansion of clay-based modelling (CBM) practice (Kooloos et al., 2014), and previously evidenced for use within MSK anatomy (Naug et al., 2011) and veterinary anatomy (Saber et al., 2016), with positive student feedback and theorised positive impacts on visual memory processing (DeHoff et al., 2011). Students are required to physically map the muscle's

geometry and fascicular orientation onto a plastic skeleton, paying particular attention to attachment sites, locations of aponeuroses and tendons (Fig. 3). This method is proposed to be a positive learning experience for Sport and Exercise students, given extant data of positive student perceptions related to the limited evidence of alternative "hands on" novel methodologies such as body painting (Anderton et al., 2016; McMenamin, 2008). However, it may provide an enhanced anatomical understanding more aligned with traditional prosections.

The aim of this study was to assess the perceptions of students from an undergraduate programme in Sport and Exercise Science on 1) Preferred anatomy teaching tool, 2) Impact of anatomy teaching tools on learning outcome measures, 3) Ability to identify structures using ultrasound, and 4) Impact of novel anatomy teaching tools on learning.

MATERIALS AND METHODS

A compulsory module titled 'Functional Anatomy of the Musculoskeletal System and Sports Medicine' was completed by 48 students as part of their second-year Sport and Exercise Science programme. During the last week of module delivery, students were invited to complete an anonymous Online MS Forms Survey on the anatomy teaching tools they had used throughout the module. All participants were required to complete informed consent prior to accessing the questionnaire. The survey contained 4 sections: Part 1 – "Ranking of Teaching Tools", Part 2 – "Learning Outcome Measures for different Teaching Tools", Part 3 – "Ability to Identify Structures using Ultrasound", Part 4 – "Novel Teaching Tools Impact on Learning". Ethical approval was granted by the University of Nottingham, School of Life Sciences Ethics Committee. Inclusion of prosections for teaching is covered under the University of Nottingham Education Licence: 12085.

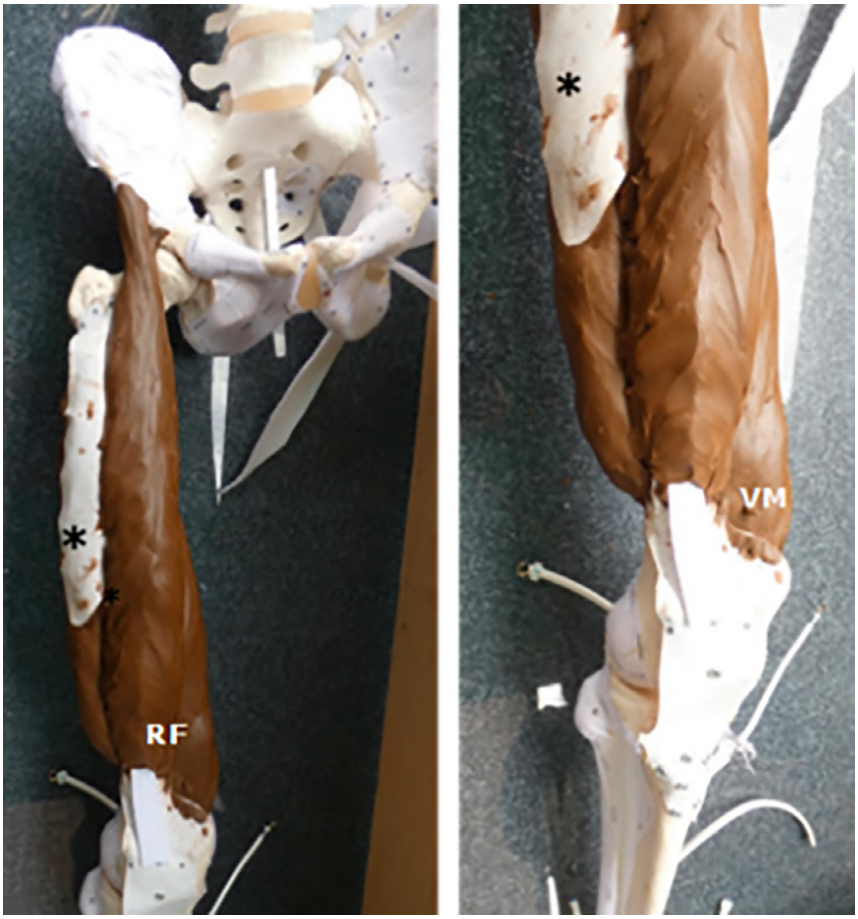

Fig. 3.- Example of Muscle Modelling of the quadricep musculature (brown modelling wax is used here). Left image demonstrates the attachment of RF rectus femoris, VM vastus medialis, at their proximal attachment with aponeuroses (*) intact. Right image: close up of the distal attachment to patellar tendon. The Muscle modelling requires attention to the geometry of the muscle and their architecture for example the fusiform shape of the RF muscle and fascicle direction.

Module Delivery

This module delivered repeated teaching to class sizes of 24 students, undertaking a 2-hour practical session in the Anatomy Suite for a consecutive two-week period, followed by a sports medicine session within the third week. Practical content was supported by their Virtual Learning Platform for lecture material. Each three-week block was focussed on the functional anatomy of a joint. Students were provided with guidance on the muscles to be modelled, which elastics to use and how to access 3D models or anatomy software subscriptions. The first of the 2-part sessions focussed on prosections, geometry and muscle modelling with the second outlining palpation, functional movements within sporting scenarios and ME tasks, with sports medicine focusing on injuries and incorporating ultrasound.

Delivery of Anatomy Teaching Tools

Sessions were designed to develop a multi-directional pedagogical feedback loop through training aspects of spatial metacognition. In contrast to historical anatomical methods, memorisation of muscle names was of least importance, whilst appreciation of functionality was deemed the key objective. Students were provided with a list of muscles and novel 3D models of force lines. Learners were then required to construct muscle models with modelling wax and then, in a following session, to re-call these attachment points by manually attaching a 'muscle elastic' which replicates the force line. Ultrasound was used to demonstrate living anatomy of an area, and as such the contractile elements displayed live on screen were useful for assessing the direction of pull and muscle fibre directions.

Questionnaire

Ranking of Anatomy Teaching Tools

Students were asked to rank all anatomy teaching tools (cadaveric prosections, electronic resources, printed resources, ME, muscle modelling, ultrasound and plastic models) in order of preference, consistent with work by Abdullah et al. (2021). Tools were ranked from 1 (Most Preferred) to 7 (Least Preferred).

Perception of Meeting Learning Outcomes

For each teaching tool (cadaveric prosections, electronic resources, printed resources, ME, muscle modelling, ultrasound and plastic models), students were asked to rate the tool in relations to a series of statements, similar to the work by Abdullah et al. (2021). For each statement, a 5-point Likert scale was used, whereby 1 = Strongly Disagree, and 5 = Strongly Agree. The learning outcome statements that participants rated for each teaching tool were as follows:

"This Tool developed my knowledge of gross anatomy."

"This Tool enabled me to identify key anatomical structures."

"This Tool helped me to achieve my Learning Outcomes."

"This Tool enabled me to recognise the spatial relationship between anatomical structures."

"This Tool improved my learning experience."

"This Tool acknowledged the clinical aspects of sports and exercise science."

Identify Structure Using Ultrasound

Questions relating to students' ability to identify different anatomical structures were sourced from Swamy and Searle (2012). Students were asked how easily they were able to identify the anatomical structures of Bone, Muscle, Tendon, Nerve and Vessels when using ultrasound. Students could select the following statement that best suited their ability to identify each structure:

"Not Able."

"With Difficulty."

"Able."

"Easily."

Novel Teaching Tools Perceived Impact on Learning

Questions related to novel teaching tools impact were sourced and adapted from Swamy and Searle (2012). Students were asked questions on the impact of learning novel teaching tools had. The three novel teaching tools were ultrasound, muscle modelling and ME. For the question "Did this

tool help improve your understanding?" students could answer:

"No", "Somewhat", "Quite a lot" or "Considerably".

For the question "Was this tool helpful in your learning?", students could answer:

"No", "Limited", "Useful" or "Essential".

For the question "Would you recommend using this tool?", students could answer:

"No", "Possibly", "Probably" or "Yes".

Statistical analysis

All the analysis was performed using IBM SPSS Statistics Version 28 software, with a critical level of statistical significance set at 5%. All data was ordinal, as such non-parametric tests were used only. Wilcoxon Singed-Rank tests with Bonferroni Correction were used to test for differences between anatomy teaching tools, for the outcome measures of knowledge, identifying structures, meeting learning outcomes, recognise spatial learning experience, clinical aspects and ranking. Chi Squared Goodness of Fit Test was used to identify significant differences in frequency of answers for structural identification using the ultrasound, along with novel techniques effect on learning (these statistics are presented relevant to a uniform distribution). Data were presented as median (inter-quartile range) where relevant.

RESULTS

Overall, 30 students completed the survey. However, two students failed to respond to all the questions, and hence a total of 28 student responses have been included in the data analysis.

Comparison of Anatomy Teaching Tools

For developing knowledge of gross anatomy, both cadaveric prosections (P=.0010) and electronic resources (P<.001) scored 40% higher than ultrasound. In addition, electronic resources score 20% higher than plastic models (P=.012). No other differences were identified between anatomy teaching tools for developing knowledge of gross anatomy (P>.05, Table 1).

For identifying key structures, cadaveric prosections scored 40% and 20% higher than ultrasound (P=.001) and printed resources (P=.010), respectively. In addition, electronic resources scored 40% higher than ultrasound (P=.029). No other differences were identified between anatomy teaching tools for identifying key structures (P>.05, Table 1).

For achieving learning outcomes, electronic resources scored 40% and 20% higher than ultrasound (P<.001) and plastic models (P=.014), respectively. No other differences were identified between anatomy teaching tools for achieving learning outcomes (P>.05, Table 1).

For recognising spatial relationships between anatomical structures, cadaveric prosections scored 40%, 20% and 40% higher than printed resources (P<.001), ultrasound (P=.015) and ME (P=.023), respectively. In addition, electronic resources scored 25% higher than printed resources (P=.001). No other differences were identified between anatomy teaching tools for recognising spatial relationships between anatomical structures (P>.05, Table 1).

Table 1. Student rating of different anatomy teaching tools on perceived achievement of learning outcomes.

	Printed Resources	Electronic Resources	Plastic Models	Muscle Modelling	Cadaveric Prosections	US	ME
Knowledge	4.0 (1)	5.0 (1)^{U,PM}	4.0 (1)	4.0 (1)^{U}	5.0 (1)	3.0 (1)	4.0 (2)
Identify Structures	4.0 (1)	5.0 (1)^{U}	4.0 (1)	4 (2)	5.0 (0.5)^{U,PM}	3.0 (1)	4.0 (2)
Learning Outcomes	4.0 (1.5)	5.0 (1)^{U,PM}	4.0 (1)	4.0 (1.5)	4.0 (1)	3.0 (1)	4.0 (2)
Recognise Spatial	3.0 (1)	4.0 (1.5)^{PR}	4.0 (1)	4.0 (2)	5.0 (1)^{PR,U,ME}	4.0 (1)	3.0 (2)
Learning Experience	4.0 (2)	5.0 (1)	4.0 (2)	5.0 (1)	5.0 (0)^{PM,PR}	4.0 (1.5)	4.0 (2)
Clinical Aspects	3.0 (1)	4.0 (2)	4.0 (1)	4.0 (1)	4.0 (1)^{PR}	4.0 (2)	4.0 (1)

Data presented as Median (Inter-Quartile Range). US = Ultrasound, ME = Muscle Elastics. U denotes significantly different for US, PM denotes significantly different from Plastic Models, PR denotes significantly different from Printed Resources, ME denotes significantly different from Muscle Elastics (P<.05).

For improving the student learning experience, cadaveric prosections scored 20% higher than both plastic models (P=.005) and printed resources (P=.020). No other differences were identified between anatomy teaching tools for improving the student learning experiences (P>.05, Table 1).

For acknowledging clinical aspects of Sport and Exercise Science, cadaveric prosections scored 25% higher than printed resources (P=.023). No other differences were identified between anatomy teaching tools for acknowledging clinical aspects associated with Sport and Exercise Science (P>0.05, Table 1).

Student Overall Anatomy Teaching Tool Ranking

For overall rankings, cadaveric prosections were shown to be ranked 60% higher than printed resources (P=.001), 60% and 67% higher than plastic models and ultrasound, respectively (P<.001). Muscle modelling ranked 50% higher than ultrasound (P=.001), in addition ME (P=.014) and electronic resources (P=.019) both ranked 50% and 33% higher than ultrasound, respectively. No other differences were reported for overall ranking between anatomy teaching tools (P>.05). Data are presented in Fig. 4, even though statistical difference is not presented here for clarity.

Identifying Structures with Ultrasound

The frequency of students able to "Easily" identify bone and muscle using ultrasound was lower than expected (P<.001), while no students selected "Not Able" to identify Bone or Muscle. The frequency of students that selected "Not Able" and Able" to identify Tendons was lower than expected (P<.001 and P<.01, respectively), while the frequency of students that selected "with difficulty" to identify tendons was higher than expected (P<.05). No students selected being able to "Easily" identify either Tendon or Nerve structures. The frequency of students that selected "Able" to identify Nerve structures was lower than expected (P<.001). The frequency of students "Able" and "Easily" identify Vessel structures using Ultrasound was lower than expected (P<.001). No other differences in expected frequency were identified (P>.05, Table 2).

Student Perception of Novel Teaching Tools on Understanding and Learning

Ultrasound

For ultrasound, the frequency of students that selected "No" (P<.001), "Quite a Lot" (P=.004) or "Considerably" (P=.004), were lower than expected, for the question "Did this tool help improve your understanding?". The frequency of students that selected "Essential" (P<.001) was lower than expected for the question "Was this tool helpful in your learning?", while no students selected "No". The frequency of students that selected "Possibly" (P<.001) or "Probably" (P<.001) were lower than expected for the question "Would you recommend using this tool?", while no students selected "No" (Table 3).

Muscle Modelling

For muscle modelling, the frequency of students that selected "No" (P<.001) or "Somewhat" (P<.001) were lower than expected, for the question "Did this tool help improve your understanding? The frequency of students that selected "Limited" (P<.001) was lower than expected for the

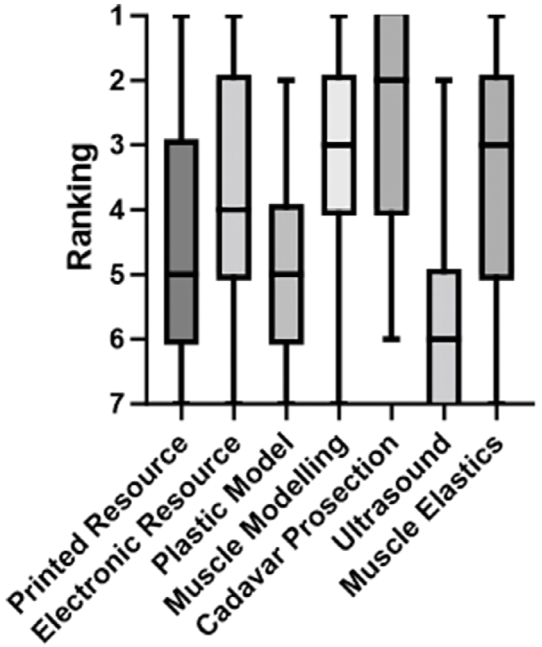

Fig. 4.- Anatomy Teaching Tools Ranked in Preference. Data presented as Median, Inter-quartile range, minimum and maximum. For clarity, statistical significances are described in the text only and not presented on the Figure.

Table 2. Student perceptions of ability to identify structures with ultrasound.

	Bone	Muscle	Tendon	Nerve	Vessel
Not Able	-	-	4%***	48%	44%
With Difficulty	33%	48%	74%*	44%	37%
Able	48%	48%	22%**	7%***	15%***
Easily	19%***	4%***	-	-	4%***

Data presented percentages of students. Significantly different frequency of students is denoted by *<.05, **<.01, or ***<.001.

question "Was this tool helpful in your learning?", while no students selected "No". The frequency of students that selected "No" (P<.001) or "Probably" (P<.001) were lower than expected for the question "Would you recommend using this tool", while no students selected "Possibly" (Table 3).

Muscle Elastics

For ME, the frequency of students that selected "No" (P<.001), "Somewhat" (P=.034) or "Quite a Lot" (P=.034), were lower than expected, for the question "Did this tool help improve your understanding?". The frequency of students that selected "No" (P<.001) or "Limited" (P<.001) was lower than expected for the question "Was this tool helpful in your learning?". The frequency of students that selected "No" (P<.001), "Possibly" (P<.001) or "Probably" (P=.001) were lower than expected for the question "Would you recommend using this tool?" (Table 3).

DISCUSSION

This study aimed to assess student perceptions of a wide range of teaching tools associated with the delivery of anatomy teaching, for Sport and Exercise Science students. Prosections were identified as the students top-ranked tool, with ME and muscle modelling ranked 2nd and 3rd respectively. Ultrasound was identified to improve students understanding only "Somewhat", with students denoting difficulty in identifying structures when using ultrasound. In comparison, muscle modelling and ME as novel techniques were shown to have higher student perception of improving understanding and being helpful in their learning.

Table 3. Student perception of novel teaching tools on understanding and learning.

	US	Muscle Modelling	ME
	Did this tool help improve your understanding?		
No	4%***	4%***	4%***
Somewhat	52%	7%***	30%*
Quite a lot	22%**	41%	30%*
Considerably	22%**	48%	37%
	Was this tool helpful in your learning?		
No	-	-	4%***
Limited	37%	7%**	11%**
Useful	48%	52%	52%
Essential	15%***	41%	33%
	Would you recommend using this tool?		
No	-	7%***	4%***
Possibly	15%***	-	11%***
Probably	15%***	7%***	19%**
Yes	70%	86%	67%

Data presented as percentage of students. US = Ultrasound, ME = Muscle Elastics. Significantly different frequency of students is denoted by *<.05, **<.01, or ***<.001.

Despite the use of cadaveric prosections for anatomy teaching being recognised as limited in modern teaching, with many institutions relying on alternative tools for anatomy teaching (McLachlan et al., 2004, Older, 2004), the present study identified that their use remains to be perceived an effective anatomy teaching tool by students. The cohort of SES students in the present study identified cadaveric prosections as the top-ranked teaching tool, aligning with previous evidence from Elizondo-Omaña et al. (2005), identifying the superiority of active experimentation and reflective observation within learning (Fig. 1). This does however contrast with Anderton et al. (2016), who identified cadaveric prosections were shown to be the 5th most popular anatomy teaching tool for Sport and Exercise Science students. These contrasting findings provide further evidence that student perceptions are impacted by individual programme expectations, while furthering the need for variety in anatomy teaching tools (Davis et al., 2014).

The present study demonstrated that ultrasound was the least preferred anatomy teaching tool, with students struggling to identify anatomical structures with this method. Previous work has focused on ultrasound use in medical teaching, in which it has been shown to be a useful anatomy teaching tool (Birrane et al., 2018, Brown et al., 2012). This is attributable to potential career requirements of understanding images such as MRI or CT scans, and experience of 2D-3D spatial awareness. However, ultrasound use is becoming an increasingly prominent skill in sport and health (Paoletta et al., 2021, Orlandi et al., 2016), as such further investigation into the effective teaching of ultrasound in sport-and-health-related degrees may be beneficial. Previous work has suggested that ultrasound teaching needs to be a highly frequent event, with sufficient duration and small class sizes, in order to develop proficiency (Bullen et al., 2020). Despite some issues with ultrasound, 70% of students in the present study recommended it as a teaching tool, in line with previous non-medical student cohorts (Edwards et al., 2023, Bullen et al., 2020). The benefit of identifying living anatomy complements the 'reflective observation' segment of the learning feedback loop, allowing students to visualise the MSK component at rest and with movement. By physically performing the movements themselves, the visual concept of muscle contraction or relaxation may be beneficial. The integration of asynchronous materials such as line diagrams may be a useful addition to teaching, as demonstrated previously (Swamy and Searle, 2012), along with consideration of expertise, time and frequency of integration. In addition, consideration may be needed as to when ultrasound is utilised, as it may be a more beneficial tool once students have developed core anatomy understanding.

The present study has demonstrated ME and muscle modelling as novel methodologies that are preferable anatomy teaching tools, with 67% and 86% of students recommending them for future learning, respectively. These findings are consistent with findings in medical and veterinary anatomy teaching (Naug et al., 2011, Saber et al., 2016), whereby it is hypothesised that these 3D and hands on methods promote active learning and are likely to help promote visual spatial learning of anatomy (DeHoff et al., 2011). While promoting active learning, ME offers less potential error in its use compared to muscle modelling. However, ME develops understanding of functional movements relevant to real world tasks, rather than spatial understanding (Bradley et al., 2022). Despite these positives, the authors' experience denotes that muscle modelling requires an elevated level of supervision and instructions, whereby it is important to ensure that muscle modelling is an accurate representation of real anatomy.

Novel techniques and Learning Theory

The development of both ME and muscle modelling in the present study has been guided by constructivist learning theories (Friedlander et al., 2011) and the Kolb's Experiential Learning Theory (ELT), whereby learning is a constant process which is built through transformation of experience and knowledge gain (Kolb, 2014). These novel concepts developed for SES student modules were designed to provide engaging and interactive teaching, whereby students would experience deep learning and application of knowl-

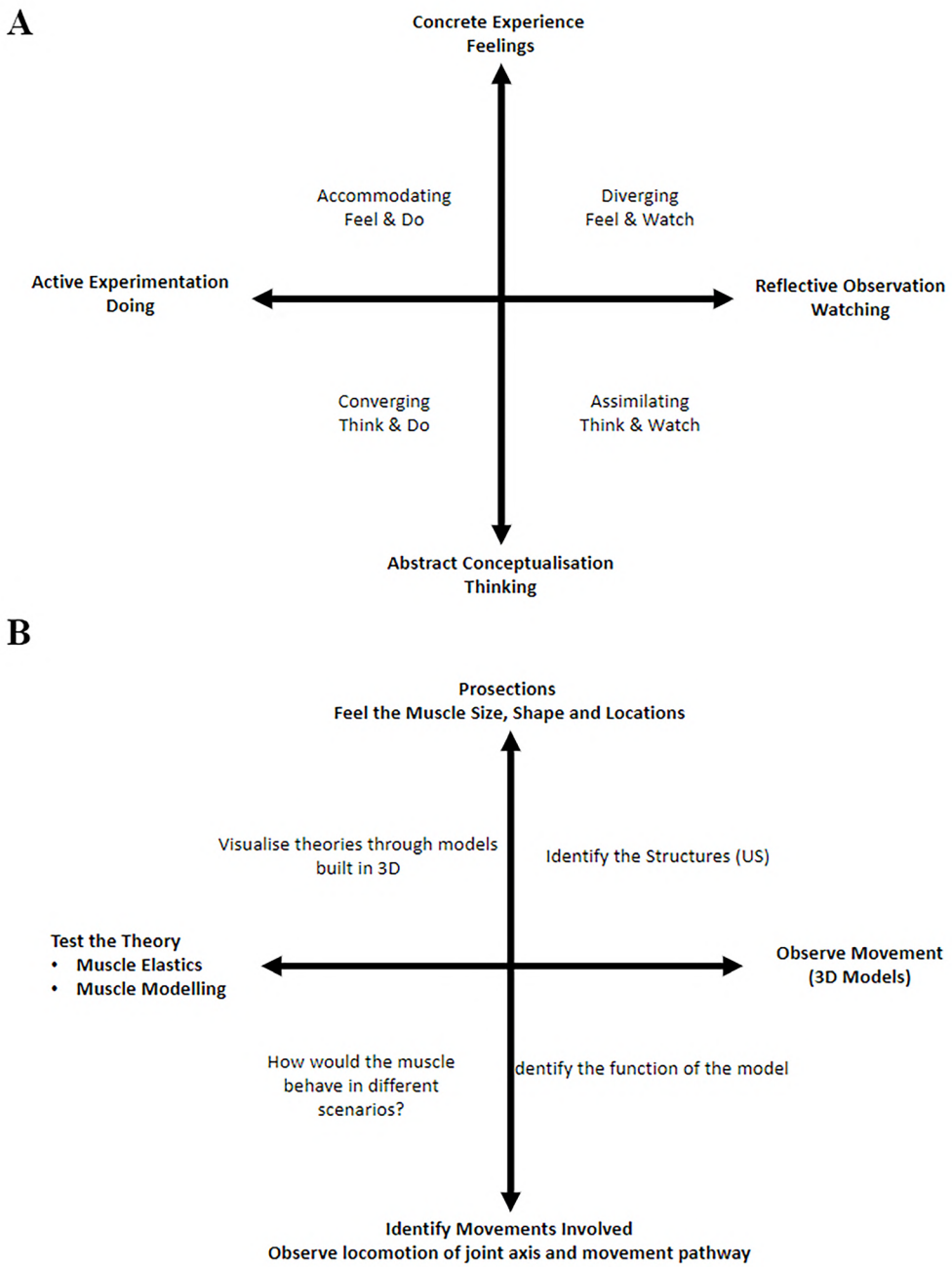

Fig. 5.- (A) Experiential theory feedback loop (Kolb, 1984). **(B)** Feedback loop with associated traditional (black) and novel (blue) anatomy teaching tools which reflect key pillars of reflective observation, abstract conceptualisation, active experimentation and concrete experience in relation to musculoskeletal anatomical principles for a SES cohort within a workshop setting.

edge to clinical context (Fig. 5). These novel concepts would be comparable to work by Shapiro et al. (2023), whereby the social interaction between learners enhances the approach by challenging learners at each stage of the cycle. By engaging the learners, this would allow secondary activities that adopt a four-staged constructivist cycle allowing reflection, observation, conceptualisation, and experimentation (Mota et al., 2010) (Fig. 4). Both ME and muscle modelling feed into the active experimentation pathway of the learning cycle. These novel methods offer an opportunity to broaden the learning cycle feedback loop, in comparison with traditional teaching tools such as dissection and cadaveric prosection, which lack input on reflective observation and feeling, in relation to musculoskeletal movement. The nature of living ultrasound complements movement, feeling and watching, embodying the aspect of reflective observation. Similarly, the group nature of the ME and muscle modelling offers opportunity for abstract conceptualisation.

Limitations

Although the students perceived benefits of these novel anatomy teaching tools, one of the key challenges for delivery of similar teaching methods for wider use in higher education was staff workload, including the duration of planning, preparation, and supervision. Skeletons required modification prior to muscle modelling to enable adhesion of wax, in addition to adaptations for the attachment of ME. Considerable time was dedicated to laboratory preparation, including designating appropriate prosections, movement-related tasks and group activities. The authors acknowledge that this study focuses on the anatomy teaching tools currently being delivered by their own institution, for which the access to some of these may not be relevant to all other higher education institutions. However, the authors hope that some of the teaching tools discussed can help to widen current teaching tool portfolios that may currently be considered for anatomy teaching.

CONCLUSIONS

This study examined the use of novel and innovative anatomy teaching tools used in an undergraduate SES degree, and compared the student perceptions of these to some more traditional teaching tools. Cadaveric prosections were the most preferred anatomy teaching tool, yet may not be a feasible tool for many institutions. Novel tools of ME and muscle modelling, however, were shown to be effective teaching tools, alongside electronic resources, and could be integrated into teaching to provide a wide range of learning modalities. Conversely, ultrasound appears to be a less effective method of learning for undergraduates and may be better suited for postgraduate study once foundational anatomical knowledge is established, or further research on supportive material to support undergraduate ultrasound teaching may be required.

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