Developing and evaluating an online learning tool to improve midwives' accuracy of visual estimation of blood loss during waterbirth: an experimental study

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ABSTRACT

Objective: the principal objective was to test the effectiveness of an online learning tool to improve midwives' accuracy of blood loss estimations in a birthing pool environment. The secondary objective was to assess the acceptability of the online learning tool to the midwives using it.

Design: a one group pre-test post-test experiment with immediate and six weeks follow-up to test ability together with an online questionnaire to assess perceived usefulness of an online learning tool.

Setting: a large NHS maternity hospital comprising an acute care obstetric unit, a small district unit labour ward, one alongside midwifery-led unit and three freestanding midwifery-led units.

Participants: volunteer NHS employed midwives who had experience in caring for women labouring and giving birth in water *(n=24).*

Intervention: an online learning tool comprising six randomly ordered short video simulations of blood loss in a birthing pool in real time, and a tutorial giving verbal and pictorial guidance on making accurate blood loss estimations in water was developed then piloted. Midwives' accuracy scores for estimating blood loss in each of the videos were calculated at three timepoints; pre and immediately post the learning component, and six weeks later. The estimated blood loss volume was subtracted from the actual blood loss volume, to give the difference between estimated and real blood loss in millilitres(ml) which was then converted to percentage difference to standardise comparison across the six volumes. The differences between pre- and post-learning for each of the six blood volumes was analysed using a repeated measures ANOVA. Statistical significance was set at $p<0.05$. An online questionnaire incorporated questions using Likert scales to gauge confidence and competence and free text. Free text responses were analysed using a modified form of inductive content analysis.

Findings: 22 midwives completed the online learning and immediate post-test, 14 completed a post-test after six weeks, and 15 responded to the online questionnaire. Pre-test results showed under-estimation of all blood loss volumes and particularly for the two largest volumes (1,000 and 1,100 ml). Across all volumes, accuracy of estimation was significantly improved at post-test 1. Accuracy diminished slightly, but overall improvement remained, at post-test 2. Participants rated the online tool positively and made suggestions for refining it.

Key conclusions and implications for practice: This is the first study measuring the accuracy of midwives' blood loss estimations in a birthing pool using real-time simulations and testing the effectiveness of an online learning tool to improve this important skill. Our findings indicate a need to develop interventions to improve midwives' accuracy at visually estimating blood loss in water, and the potential of an online approach. Most women who labour and/or give birth in water do so in midwifery-led settings without immediate access to medical support. Accuracy in blood loss estimations is an essential core skill

Key words. Waterbirth; blood loss estimations; video simulations; online learning tool; experimental study; longitudinal

Introduction

Globally, postpartum haemorrhage (PPH), defined as a blood loss of 500mls or more within 24 hours of giving birth, is estimated to affect between two and thirteen percent of all childbearing women (World Health Organisation, 2018, Knight et al., 2017). PPH is associated with a quarter of all perinatal deaths (World Health Organistion, 2018), and rates in middle and high-income countries are rising Midwives therefore need to be able accurately to quantify blood loss to ensure that women receive appropriate and timely treatment.

Although tools have been developed to help improve midwives' abilities to estimate blood loss following childbirth on land, an increasing number of women in several countries are now choosing to give birth in water (Burns et al., 2012, Henderson et al., 2014, Kavosi et al., 2015, Menakaya et al., 2013, Mollamahmutoğlu et al., 2012, Nicholls et al., 2015, Ministry of Health. New Zealand, 2018). In the UK, a rising number of birth pools are being installed and used in midwifery led units (Which? Birth Choice, 2016), and the two latest Care Quality Commission's four week surveys for England which reported on waterbirth showed an increase in the proportion of women who had a waterbirth; 9% (793) of the 59% (8,814/14,940) of women who had a spontaneous vaginal birth for 2015 compared with 8% (815) of the 60% (10,188/16,981) who had a spontaneous vaginal birth in 2013 (Care Quality Commission, 2015). This upward trend in waterbirth and a significant increase in midwifery led units in England (Walsh et al., 2018) reflects a drive to normalise birth that is occurring in the wake of the Birthplace study, which showed that planning birth in a midwifery led setting increased the likelihood of normal birth for women identified as low risk (Birthplace in England Collaborative Group, 2011). Little is currently known about midwives' competence in assessing blood loss during waterbirth, and there is a dearth of evidence-based guidance or educational material to assist them in this clinical scenario. The Royal College of Midwives (RCM) states the importance of all midwives being confident and competent to support women using a birthing pool (Royal

College of Midwives, 2012). We therefore developed and tested an online learning tool to assess and improve the accuracy of midwives' estimations of blood loss in water.

Background

The volume of blood that a woman loses within the first 24 hours following childbirth varies from person to person. Assessing the amount and promptly addressing the degree to which it may compromise individual women is complex and presents a longstanding challenge for midwives and obstetricians (Bose et al., 2006). Visual estimation of the amount and rate of blood loss provides an initial reference point to gauge maternal wellbeing. In tandem, clinicians observe the woman for signs and symptoms of shock, such as feeling faint or dizzy, looking pale and clammy, low blood pressure, together with rising pulse, and respiratory rate (Paterson-Brown and Howell, 2014). During pregnancy, however, the circulating blood volume increases to around 100ml/kg of a woman's weight (Lemmens et al., 2006). This factor enables her to compensate initially and not display signs of shock until there is clear cardiovascular compromise (Buckland and Homer, 2007, Paterson-Brown and Howell, 2014). Visual assessment of blood loss is therefore an important skill, but presents a challenge because it is an inexact science. Irrespective of clinician skills and length in practice, research has consistently shown a tendency to overestimate blood loss volumes of less than 500ml and underestimate blood loss above this amount (Hancock et al., 2015, Schorn, 2010).

Tools that have been developed and tested to improve blood loss estimation during childbirth on land comprised a mix of a pictorial guide showing reconstruction of blood loss (Bose et al., 2006, Cheerranichanunth and Poolnoi, 2012 , Marine Pranal et al., 2018), clinical simulations using measured blood volumes on pads, towels, linen, lower torso and legs of a mannequin laid on a bed on blood stained linen and in vomit bowls and kidney dishes (Dildy et al., 2004, Maslovitz et al., 2008, Moscati et al., 1999, Sukprasert et al., 2006, Prasertcharoensuk et al., 2000, Razvi et al., 1996, Lilly et al., 2015), live and web-based educational sessions using mathematical formulas and comparisons with volumes of common objects (Toledo et al., 2010) and accuracy comparison between gravimetric blood loss measurement with visual estimations (Lilly et al., 2015). Findings included an overall improvement in clinicians' accuracy in their estimates, although the trend to overestimate small amounts and underestimate larger amounts persisted (Prasertcharoensuk et al., 2000, Razvi et al., 1996). The gravimetric versus visual estimation study measurements resulted in a lower error rate and greater correlation with a reduced haemoglobin for PPH <1,500 mL (Lilly et al., 2015). Three pre-test, post-test studies (Al-Kadri et al., 2014 , Dildy et al., 2004, Toledo et al., 2010) reported improved accuracy following a taught session. However, only one study explored performance beyond post-test immediately after the session, and found a significantly reduced accuracy, compared with the immediately post-test assessment (Toledo et al., 2012).

We identified three studies specifically addressing assessing blood loss during waterbirth; two were pre-test post-test -experimental studies from unpublished Masters dissertations (Beckhurst, 2015, Lim, 1994) and one described the development of a pictorial aide-memoire to assist with estimating blood loss in water (Goodman, 2015). All three were produced in the UK. Sample sizes in the two experimental studies were small, with a total of 22 midwives and 15 student midwives recorded as participants across both papers. All three authors used expired bank blood to create simulations of blood loss in water. Lim (1994) poured blood from a measuring jug into a birthing pool full of water and asked midwives to estimate the blood volume. She then added more blood and asked them to estimate the new total blood volume. She compared the results to participants' estimations of blood loss in a land-based simulation and concluded that there was a tendency to overestimate smaller blood loss volumes (50mls-400mls) and underestimate larger blood loss volumes (450mls-1,100mls) in both land and water losses. Goodman made the introduction of the blood into the water more true to life by submerging one end of a flexible plastic tube in the water, and pouring the blood in through the other end (Goodman, 2015). Blood was poured down the tube and into the pool in pulses, to mimic blood loss from a postpartum woman, and photos were taken as increasing amounts of blood entered the water. A pair of surgical gloves was filled with water and taped to the bottom of the pool to represent a woman's feet, so visibility at different blood volumes could be ascertained. Goodman's photos demonstrated how blood moves in the water, first creating a thin layer across the bottom of the pool and then gravitating in thicker layers towards the plug hole. She did not report using the pictures to test or improve practitioners' abilities in estimating blood loss. Beckhurst developed Goodman's idea further, using a similar corrugated tube to introduce the blood into the pool but introducing a live model to represent a postpartum woman and filming the entry of different amounts of blood into the water in real time (Beckhurst, 2015). As in Goodman's initiative, the blood was poured into the pool in a pulsatile manner. The submerged end of the tube was positioned between the model's legs to mimic real loss as closely as possible and the model moved her legs and arms to simulate a women following childbirth. The birthing pool used to create the videos was a standard size with a water capacity of 500 litres and 65cms deep. Allowing for water displacement of around 75 litres, the net volume was approximately 475 litres. Beckhurst made ten videos each lasting around 2.5 minutes and involving a different volume of blood loss. These were shown to student midwives, who were asked to estimate the volume of blood in each video excerpt (pre-test), repeat this exercise immediately after a teaching session (post-test 1), and again sixteen weeks later (post-test 2). The teaching session covered predisposing factors for PPH, and identification and management. Students watched snippets of the videos and were guided to signs such as the gravitation of blood towards the plug hole at higher volumes and the level of visibility of the woman's legs and feet at different volumes to facilitate their ability to estimate blood loss in water accurately. As with a couple of the land birth studies (Prasertcharoensuk et al., 2000, Razvi et al., 1996), Beckhurst identified a tendency for smaller volumes of loss to be overestimated and larger volumes to be underestimated (Beckhurst, 2015); the students' estimations were significantly more accurate immediately post the taught session, but except for estimations for 300ml, lapsed at follow-up.

Methods

This study used a mixed method design to develop and evaluate Beckhurst's study further, by incorporating the videos into an online learning tool aiming to assess and improve midwives' abilities to estimate blood loss in water. Using the same experimental one group pre-test post-test design, midwives' skills were assessed before, immediately after and six weeks after completing an online-learning session. The acceptability of the tool was assessed using an online survey consisting of open and closed questions. It was anticipated that this approach would give an indication of midwives' accuracy at estimating blood loss in water and the potential of the tool to improve this in the short and longer term, and provide data that would enable the tool to be refined and for sample size calculation for a future definitive study.

Participants and setting

Using a convenience sampling technique, this study aimed to recruit 30 midwives from a single NHS Trust in South Central England which has ten birthing pools and an average of 460 waterbirths per year excluding home births. Inclusion criteria were practising midwives who had intrapartum experience and had been the primary carer or second midwife for women giving birth in water. A sample size was not calculated for this study as it is the first involving midwives estimating blood loss in waterbirth; however, 30 participants were planned in line with recommendations for studies gathering information to calculate sample sizes for full-scale studies (Billingham et al., 2013). Midwives were invited to participate via an email which was circulated by the Head of Midwifery's personal assistant. It detailed the purpose of the study and included a participant information sheet, online consent form and a short online demographic questionnaire. Potential participants were invited to contact author 2 or 3 with further questions or to complete the consent form and demographic questions and send them to author 2 if they wished to take part. They were then sent a link to the online-learning tool. Answers to the tool questions were anonymous and could not be tracked to individual midwives. A follow-up email was sent via the Head of Midwifery's personal assistant after four weeks, thanking those who had already responded and asking more people to take part, and posters were displayed in different clinical areas in a further attempt to increase participation.

Design and Intervention

The online-learning tool consisted of two-minute videos showing blood loss in a pool in real time alongside an online tutorial on estimating blood loss in water. Six of the ten videos made by (Beckhurst, 2015) were selected and edited for use in the tool. The six videos showed blood losses of 400ml, 500ml, 700mls, 800ml, 1,000mls and 1,100mls; the volumes that proved the most difficult to estimate in Beckhurst's study. Volumes of 500 and 1000mls are also important volumes to include as they represent thresholds for a PPH and severe PPH respectively (World health Organisation, 2009). The videos were shown in a random order before and after the online tutorial, which combined still images of blood loss following waterbirth from the videos with additional images, audio and text explanations. In line with interventions shown to successfully improve midwives' abilities to estimate blood loss on land, a pictorial reconstruction of blood loss as it travels through the pool and references to easily recognisable comparators were used (Bose et al., 2006, Cheerranichanunth and Poolnoi, 2012 , Maslovitz et al., 2008, Toledo et al., 2010). Participants were asked to consider whether the blood in the pool resembled blackcurrant cordial, rosé or red wine. Using suggestions made by (Garland, 2011), they were also advised to consider the visibility of landmarks such as the live model's hands and feet and the bottom of the pool. An interactive activity asked them to view three still images from the endpoint of the videos for 200ml, 600ml and 800ml and to estimate the amount of blood loss in each. Participants were then informed of the exact amount and audio recording described the dispersal, colour and opacity of the blood, and landmark visibility through the loss for each blood volume. The online tutorial was designed to take approximately 10 minutes; however, participants could navigate forward and backward through it at their own pace. The online tool was piloted by four midwives who were not part of the participant sample. Online-learning was chosen as the mode of delivery for the tool because greater retention of knowledge and higher achievement scores in knowledge and skills have been shown using this method compared with traditional classroom learning (Jethro et al., 2012). Furthermore, this mode of delivery enables participants to adapt their experiences to meet their personal learning goals and offers them control over the subject matter, learning sequence, pace and timing of learning (Ruiz et al., 2006).

Data Collection

Pre-test

On accessing the online-learning tool, participating midwives were shown the six videos of blood entering a birthing pool. After each video, they were asked to enter their estimation of the volume of blood lost in a text box. Participants could access the tutorial on completion of this pre-test, and they could not return to the pre-test section once they accessed the tutorial. To eliminate possible order effects, the sequence in which videos were viewed was randomised across the pre and post-tests using a computer generated random number sequence (Dettori, 2010). (Table 1).

Post-test assessments

Participants were invited to complete a post-test exercise immediately after completion of the online tutorial. They were then sent an email six weeks later with links to post-test 2. The post-test exercises comprised a repetition of the pre-test, with the videos in a different order for post-test 1 and post-test 2.

Questionnaire

After completing post-test 2 six weeks following post-test 1, participants were sent a link to a separate online questionnaire, which was anticipated to take 10-15 minutes to complete. The questions in the evaluation related to overall satisfaction, clarity of content, length and pace of the online-learning package, ease of access and navigation and whether they would recommend the e-learning package to others. A mix of free text responses and opinions indicated on a five-point Likert-type scale with five signalling an extremely positive response (excellent, or strongly agree), were solicited.

Data analysis

For each of the six videos assessed at the three different time points, the midwives' estimated volume of blood loss was subtracted from the actual volume of blood loss, to give the difference between estimated and real blood loss (millilitres/ml). This was converted to percentage difference to aid comparison across the six volumes.

Measures of central tendency (mean, median) and dispersion (SD, range) were calculated after assessing the distribution for each variable. The distributions of variables were assessed using histograms. The normally distributed data were analysed using parametric tests. The difference between pre- and post-learning was assessed using a repeated measures ANOVA and if sphericity (variances of the differences) was not assumed the Greenhouse Geisser correction was used. The statistical significance was set at $p<0.05$. All analyses were conducted using SPSS v23.

In analysing responses to the evaluation questionnaire, a descriptive approach was used to present data from questions using Likert scales. Free text responses were analysed using a modified form of inductive content analysis (Elo and Kyngäs, 2008). Responses were read and grouped into themes. The number of responses within each theme was then counted to give an indication of the relative importance of each one to the respondents. The themes were grouped into two categories; ‘things that were done well’ and ‘things that could be improved’.

Findings

A total of 30 midwives expressed an interest in taking part in the study. Figure 1 below illustrates participant flow through the study. Six midwives declined to participate prior to starting the e-learning tool, leaving a sample size of 24. Two midwives’ estimations were not logged in the post-test due to a technical fault. Eight midwives did not complete the six-week post-test and seven did not complete the online questionnaire. Fourteen participants completed the study at all three time points. Participants included a mix of midwives who had been qualified for 5 years or less and more experienced practitioners. Over 60% (15) of the respondents had attended over 30 waterbirths (Table 1).

Accuracy of estimation

The percentage differences between actual and estimated blood volumes were available for 24 midwives at baseline (pre-test), 22 midwives immediately (post-test 1) after the online learning and 14 at six weeks follow up (Table 2). At baseline, estimates for all six video volumes were lower than actual volumes. For five of the six videos, the percentage difference in accuracy estimates reduced in magnitude immediately following the tutorial (post-test 1). The exception was for 700 ml for which the percentage difference changed from 9% underestimation to 9% overestimation. Two volumes (500 & 700mls) were overestimated, all others were underestimated (Table 2).

Figure 2 shows the mean difference (%) between actual and estimated blood loss for each volume, at each time point for the 14 midwives who provided data for all three timepoints. Across all six volumes, the differences between baseline and post-test were statistically significant with midwives giving more accurate visual estimates of blood loss after the tutorial (repeated measures ANOVA F (17.481) = 21.032, P<0.001). Regardless of the volume of blood estimated, the mean percentage difference between actual and estimated volumes reduced from 32% under-estimated at baseline to 9% immediately after the online tutorial. The observed increase in accuracy of their visual estimation diminished at follow-up six weeks later but was still improved from baseline (13%). The differences between the three time points were statistically significant (F 1.377,17.903) = 6.2, p=0.015, eta=0.323. Regardless of the effects of the tutorial on the accuracy of midwives' visual estimates, there was also a significant main effect of blood volume on accuracy of estimation: (F2.73, 35.5) = 12.2, P<0.001, eta=0.485. Furthermore, there was a significant interaction between the effects of the tutorial and blood volumes on midwives' accuracy of estimation F (3.90, 50.8) = 4.150, p=.006, eta=0.242. The data suggest that midwives retained their ability to estimate more accurately for, 700, 800, 1,000 and 1,100 mls but showed greater loss of accuracy for 400 and 500 mls at follow-up six weeks later (Figure 2).

Figure 3 shows the proportion of midwives who correctly estimated each volume of blood within ±50 ml. Across all volumes, except 1000mls, more participants made the correct diagnosis immediately following the online tutorial (post-test 1) than at the pre-test. In both the pre-and immediate post-test, a higher proportion of midwives correctly classified 400mls as normal loss (25%, 36% respectively) compared with higher volumes, which in a clinical situation would meet criteria for a PPH. Overall, this learning was retained at the six-week assessment.

Fifteen midwives completed the online evaluation. Figure 4 below summarises the five-point Likert-type scale results across five different categories: overall satisfaction, clarity of content, length and pace of the online learning tool, ease of access and navigation through package and recommendable to non-participants. 60% of the midwives rated their overall satisfaction with the online learning tool to be either very good or excellent, 80% thought the content was extremely clear, and 70% thought the length and pace was very good or excellent. Over 90% either agreed or strongly agreed the online learning tool was easy to navigate and access, 80% would recommend it to other midwives.

Midwives were asked to give further feedback on the tool and ways in which it might be improved using free text responses. The themes raised were grouped into two overriding categories of 'things that were done well' and 'things which could be improved'. The content of each theme, together with its frequency of occurrence, are summarised in Table 3.

Overall, the midwives' feedback provided was very positive. The videos and tutorial style were particularly well received. The main criticism of the tool was that it didn't give any feedback as to how accurate participants' estimations of blood loss were.

Discussion

This study tested and evaluated the impact of an interactive online learning tool to improve midwives' visual estimations of blood loss in a birthing pool environment. At baseline midwives underestimated all blood volumes that they were shown, and the magnitude of error was greater with higher volumes. Overall findings indicated that the online learning tool increased their accuracy in estimating blood loss and although their precision deteriorated by six weeks, it remained better than pre-test results for all blood volumes. Whilst not perfect, it is reassuring to note that midwives could more precisely identify blood volumes comprising a PPH; an essential skill to ensure timely treatment to safeguard maternal health (Royal College of Obstetricians and Gynaecologists, 2016, World Health Organisation and UNICEF, 2012). Their estimates for 400ml were the most accurate (Figure 3). Our findings echo the results of the studies by Beckhurst and Lim (Beckhurst, 2015, Lim, 1994). It is also interesting that both found improved estimations for an amount below the 500ml PPH threshold, and midwives' estimates in our study were most accurate for 400mls (Figure 3). This finding is relevant because most healthy women who have a physiological labour and spontaneous birth do not have a PPH, and waterbirth is a care option that is promoted for healthy pregnant women who experience a straightforward pregnancy (Royal College of Obstetricians and Gynaecologists and Royal College of Midwives, 2006). It is also the population who is being encouraged to give birth in midwifery led settings where most waterbirths occur (National Institute for Clinical Excellence, 2014). Therefore, midwives need to differentiate between a normal and excessive blood loss. The trend in showing greater ability when evaluating blood volumes less than 400ml extends to studies involving land birth (Briley et al., 2014, Buckland and Homer, 2007, Dildy et al., 2004, Glover, 2003, Lee et al., 2014), and one study found particular accuracy at 200ml (Yoong et al., 2010).

Midwives' feedback (Figure 4, Table 3) about the online learning tool was positive. They compared the videos favourably over still pictures; a characteristic which compared well with a single image in a study which examined blood loss following simulated land birth (Maslovitz et al., 2008). They also valued the tips and cues that the accompanying tutorial provided and liked the flexibility of being able to use the tool at their own convenience. One suggestion for improvement was to include a wider range of blood volumes; this tool only included one volume which was less than a PPH. Another was 'to show blood loss in a murky pool'. An early study involving measuring blood loss following birth on land in a pouch found that providing a description of the visual separation of amniotic fluid and blood improved clinician estimated accuracy (Haswell, 1981). This could be illustrated in a birthing pool. The very positive free text feedback from the participant who stated that she would not recommend the online learning tool indicates that she may have selected the wrong response to this question.

Another theme in the midwives' feedback centred on having more information about clinical symptoms and plans of care for each volume of blood. Linkage to the signs and symptoms that women may exhibit is important and indicates the midwives' awareness that the visual estimate of blood loss is only part of the picture that informs their decision-making in planning care (Buckland and Homer, 2007, Hancock et al., 2015, Khan et al., 2006, Paterson-Brown and Howell, 2014). A further aspect to incorporate when assessing the potential impact of blood loss is maternal weight because lighter women have a lower blood volume than heavier women, which can lead to an underestimation of blood loss for women weighing ≤70 kg (Paterson-Brown and Howell, 2014). Of course, it is worth noting that the % difference or level of inaccuracy needs to be interpreted considering the volume of blood loss as the clinical implications of inaccuracy are dependent on the actual volume of blood loss. Inaccuracy of 30% at 500 mls will be a smaller volume of blood than 30% inaccuracy of 1,000mls.

Irrespective of the visible blood volume loss, accurate identification of impending maternal compromise is a core skill requirement; however, it is not always easy to elicit. A systematic review that examined the association between blood loss and clinical signs reported on 30 studies, five of which involved women who had a pregnancy related haemorrhage, highlighted the challenge of ascertaining a reliable indicator of compromise for women during childbirth and the immediate hours following it (Pacagnella et al., 2013). Notwithstanding the few obstetric specific studies in this review, it suggested that the shock index (SI) (calculated by heart rate divided by the systolic blood pressure) could potentially provide a reliable measurement of compensatory changes occurring as a result of blood loss (Pacagnella et al., 2013). A recent retrospective cohort study (n=233 women with PPH ≥1,500 ml) which compared the SI with traditional measurement of vital signs in PPH and adjusted for confounders, reported that it compared well and suggested it could be used to determine 'alert' thresholds for use in resource poor settings (Nathan et al., 2015); a context that is comparable to the most prevalent waterbirth care settings in the sense of there being limited immediate help to hand. No single element is likely to ensure a high level of sensitivity and specificity in gauging impending compromise due to blood loss for women giving birth in water; however, a combination of optimising clinical accuracy of visual blood loss estimation in tandem with accounting for a woman's weight, observing her and using the SI may as a package enhance the safety for women who have a waterbirth.

Strengths and limitations

The strengths of the online learning tool examined in this study include authentic simulation, using a live model and real blood filmed in real time as it emerged from between the model's legs, an online tutorial which provided cues about the extent to which the blood flowed over the base of the pool to cover the model's feet and legs as participants watched, and its ease of use as a tool that they could leave and return to as and when their time permitted. It improved participant accuracy and they liked engaging with it. The sample was small however, and recruited from one maternity unit, which limits the generalisability of the findings to a wider population. Therefore, further evaluation on a larger sample involving more than a single study centre is required.

The BMI was not measured in the models involved in creating the videos; however, they were all average weight (≤70 kilos) and height (164 cm) and represented the eligibility criteria recommended for birthing pool use and for planning birth in midwifery led settings in the UK. A petite, light (50-60 kg) woman with a height of 157 cm or less will require a lower volume of water in a typical birthing pool; it could therefore be argued that the tool's guidance parameters may potentially lead to an over-diagnosis of excessive blood loss for such women. It is therefore important to highlight the impact that less blood loss may have on petite, light women as they have a lower circulating blood volume compared to taller, heavier women.

Suggestions for tool development

The tool could include blood volumes of less than 400ml to test and develop midwives' ability to accurately differentiate between normal versus excessive blood loss. To develop and refine clinical assessment of maternal health, the tutorial could incorporate specific information about signs and symptoms of maternal compromise; an addition which could test using the shock index as an indicator of maternal condition.

Conclusion

This is the first study to examine the impact of an innovative online learning tool designed to improve midwives' ability to accurately estimate a range of blood volumes in a standard sized birthing pool, and to ascertain their views about its usefulness. Results showed that the tool, using videos of a range of blood volumes filmed in real time with an accompanying online tutorial and involving a human model simulation in a birthing pool may improve midwives' accuracy in their visual estimations. The midwives' evaluation illustrates their eagerness to know how accurately they gauged the blood loss and to understand how women may present across the range of volumes. It identified the importance of linking visual blood loss estimations with women's wellbeing, and the need to facilitate midwives' skills in accurately assessing normal as well as excessive blood volumes.

Conflict of interest

The authors have no conflict of interest in connection with this paper and are responsible for the content and writing the paper.

Ethical approval for the study was granted by the researchers' university and R&D agreement from the NHS Trust which formed the study site. Participation in the study was voluntary and participants were free to withdraw at any time, without justification. All personal data was anonymised, and data was stored securely on a password protected computer.

REFERENCES

Al-Kadri, H., Dahlawi H, Al Airan M, Elsherif E, Tawfeeq N, Mokhele Y, Brown D & Tamim H. 2014 Effect of education and clinical assessment on the accuracy of postpartum blood loss estimation http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3994970&tool=pmcent [Online]. Available: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3994970&tool=pmcent [Accessed 25th January 2018].

Beckhurst, M. 2015. Estimating blood loss following water birth: the impact of a video training session on student midwives' ability and confidence to accurately estimate blood loss and recognise postpartum haemorrhage in a water birth environment. MSc, Oxford Brookes University.

Billingham, S., Whitehead, A. & Julious, S. 2013. An audit of sample sizes for pilot and feasibility trials being undertaken in the United Kingdom registered in the United Kingdom Clinical Research Network database. [Online]. Available: http://bmcmedresmethodol.biomedcentral.com/articles/10.1186/1471-2288-13-104. [Accessed 20th January 2018].

Birthplace in England Collaborative Group. 2011. Perinatal and maternal outcomes by planned place of birth for healthy women with low risk pregnancies: the Birthplace in England national prospective cohort study. BMJ [Online], 343. Available: http://www.ncbi.nlm.nih.gov/pubmed/22117057 [Accessed 10th January 2018].

Bose, P., Regan F & Paterson-Brown S 2006. Improving the accuracy of estimated blood loss at obstetric haemorrhage using clinical reconstructions. BJOG, 113, 119-124.

Briley, A., Seed P, Tydeman G, Ballard H, Waterstone M, Sandall J, Poston L, Tribe R & Bewley S 2014. Reporting errors, incidence and risk factors for postpartum haemorrhage and progression to severe PPH: A prospective observational study. BJOG, 121, 876-888.

Buckland, S. S. & Homer, C. S. E. 2007. Estimating blood loss after birth: using simulated clinical examples. Women and Birth, 20, 85-88.

Burns, E. E., Boulton, M. G., Cluett, E., Cornelius, V. R. & Smith, L. A. 2012. Characteristics, Interventions, and Outcomes of Women Who Used a Birthing Pool: A Prospective Observational Study Birth, 39, 192-202.

Care Quality Commission. 2015. Maternity services survey 2015 [Online]. London: CQC. Available: https://www.cqc.org.uk/content/maternity-services-survey-2015 [Accessed 26th March 2017].

Cheerranichanunth, P. & Poolnoi, P. 2012 Using blood loss pictogram for visual blood loss estimation in cesarean section. J Med Assoc Thai., 4, 550-556.

Dettori, J. 2010. The random allocation process: two things you need to know [Online]. Evid Based Spine Care J. 1(3): 7–9. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3427961/ [Accessed 24th February 2017].

Dildy, G., Paine Ar, George Nc & Velasco C 2004. Can teaching significantly imporove visual estimation? Obstet Gynecol, 104, 601-606.

Elo, S. & Kyngäs, H. 2008. The qualitative content analysis process. J Adv Nurs, 62, 107–115

Garland, D. 2011. Revisiting Waterbirth: An attitude to care, Palgrave McMillan, UK.

Glover, P. 2003. How accurate is your estimation? Aust J Midwifery, 16, 21-24.

Goodman, A. 2015. Pictorial estimation of blood loss in a birthing pool-an aide memoire. Practising Midwife 18, 29-32.

Hancock, A., Weeks, A. & Lavender, T. 2015. Is accurate and reliable blood loss estimation the 'crucial step' in early detection of postpartum haemorrhage: an integrative review of the literature. https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-015-0653-6 [Accessed January 2018]

Haswell, J. 1981. Measured blood loss at delivery. J Inidana State Med Assoc, 74, 34-36.

Henderson, J., Burns, E., Regalia, A., Casarico, G., Boulton, M. & Smith, L. 2014. Labouring women who used a birthing pool in obsteric units in Italy: prospective observational study [Online]. London. Available: https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/1471-2393-14-17 [Accessed 25th January 2018]

Jethro, O., Grace, A. & Thomas, A. 2012. E-Learning and its effects on teaching and learning in a global age [Online]. International Journal of Academic Research in Business and Social Sciences. 2(1), 203-210. Available: http://www.hrmars.com/admin/pics/484.pdf [Accessed 28th January 2018].

Kavosi, Z., Keshtkaran A, Setoodehzadeh F, Kasraeian M, Khammarnia M & M, E. 2015. A Comparison of Mothers' Quality of Life after Normal Vaginal, Cesarean, and Water Birth Deliveries, IJCBNM., 3, 198-204.

Khan, K., Wojdyla D, Say L, Gülmezoglu Am & Van Look Pf. 2006. WHO analysis of causes of maternal death: a systematic review. Lancet [Online], 367. Available: https://www.ncbi.nlm.nih.gov/pubmed/16581405 [Accessed 25th January 2017].

Knight, M, K., Nair, M., Tuffnell, D., Shakespeare J & Sara Kenyon, J. J. K. E. 2017. Saving Lives, Improving Mothers' Care. MBRRACE-UK [Online]. Available: https://www.npeu.ox.ac.uk/downloads/files/mbrrace-uk/reports/MBRRACE-UK%20Maternal%20Report%202017%20-%20Web.pdf [Accessed 30th August 2018].

Lee, D., Woody D, Asa W & Jr W 2014 Accuracy of Blood Loss Estimations Among Anesthesia Providers. American Association of Nurse Anesthetists., 82, 300-307.

Lemmens, H. J., Bernstein, D. P. & Brodsky, J. B. 2006. Estimating blood volume in obese and morbidly obese patients. Obes Surg, 16, 773-776.

Lilly, G., Burkett-St-Laurent D, Precious E, Bryynseels D, Kaye A, Sanders J, Alikhan R, Collins Pw, Hall Je & Collis Re 2015. Measurement of blood loss during postpartum haemorrhage. International Journal of Obstetric Anesthesia, 24, 8-14.

Lim, S. 1994. A study to compare midwives' visual estimation of blood loss in "water" and on "land" [Online]. As cited in Royal College of Obstetricians and Gynaecologists (2009) Immersion in Water During Labour and Birth (RCOG/Royal College of Midwives Joint Statement No. 1): RCOG. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.544.6516&rep=rep1&type=pdf [Accessed 25th January 2018].

Marine Pranal, Aline Guttmann, Lemlih Ouchchane, Ines Parayre, Olivier Rivière, Sylvie Leroux, Sylvie Bonnefont, Anne Debost-Legrand & Françoise Vendittelli 2018. Do estimates of blood loss differ between student midwives and midwives? A multicenter cross-sectional study. Midwifery, 59, 17-22.

Maslovitz, S., Barkai G, Lessing Jb & Ziv A 2008. Improved accuaracy of postpartum blood loss estimation as assessed by simulation. Acta Obstet Gynecol 87, 929-934.

Menakaya, U., Albayati, S., Vella, E., Fenwick, J. & Angstetra, D. 2013. A retrospective comparison of water birth and conventional vaginal birth among women deemed to be low risk in a secondary level hospital in Australia. Women and Birth 26, 114-118.

Ministry of Health. New Zealand. 2018. Maternity Services [Online]. MOH New Zealand. Available: https://www.health.govt.nz/our-work/life-stages/maternity-services [Accessed 30 August 2018].

Mollamahmutoğlu, L., Moraloğlu, Ö., Özyer, Ş., Akın Su, F., Karayalçın, R., Hançerlioğlu, N., Uzunlar, Ö. & Dilmen, U. 2012. The effects of immersion in water on labor. J Turkish-German Gynecol Assoc 45-49.

Moscati, R., Billittier Aj, Marchall B, Fincher M, Jehle D & Braen R 1999. Blood loss estimation by out-of-hospital emergency care providers. Prehosp Emerg Care, 3, 239-242.

Nathan, H., El Ayadi A, Hezelgrave Nl, Seed P, Butrick E, Miller S, Briley A, Bewley S & Ah., S. 2015. Shock index: an effective predictor of outcome in postpartum haemorrhage? BJOG, 122, 268-275.

National Institute for Clinical Excellence. 2014. Intrapartum care for healthy women and babies NICE guidelines [CG190] Available: http://www.nice.org.uk/guidance/cg190/evidence [Accessed 28th January 2018].

Nicholls, S., Hauck Yl, Bayes S & J., B. 2015. Exploring midwives' perception of confidence around facilitating water birth in Western Australia: A qualitative descriptive study. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S026661381500279X [Accessed 18th January 2017].

Pacagnella, R. C., Souza, J. P., Durocher, J., Perel, P., Blum, J., Winikoff, B. & Gulmezoglu, A. M. 2013. A Systematic Review of the Relationship between Blood Loss and Clinical Signs [Online]. PLoS One. Available: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0057594 [Accessed 25th January 2018].

Paterson-Brown, S. E. & Howell, C. E. 2014. Managing Obstetric Emergencies and Trauma: The MOET Course Manual, Cambridge University Press,, Cambridge.

Prasertcharoensuk, W., Swadpanich U & P, L. 2000. Accuracy of the blood loss estimation in the third stage of labor. Int J Gynaecol Obstet, 71, 69-70.

Razvi, K., Chua S, Arulkumaran S & Ratnam Ss 1996. A comparison between visual estimation and laboratory determination of blood loss during the third stage of labour. Aust NZ J Obstet Gynaecol, 36, 152-154.

Royal College of Midwives. 2012. Evidence Based Guidelines for Midwifery-Led Care in Labour. Immersion in Water for Labour and Birth [Online]. London: Royal College of Midwives. Available: https://www.rcm.org.uk/sites/default/files/Supporting%20Women%20in%20Labour_1.pdf [Accessed 14th January 2017].

Royal College of Obstetricians and Gynaecologists. 2016. Postpartum Haemorrhage, Prevention and Management (Green-top 52) [Online]. London. Available: https://www.rcog.org.uk/en/guidelines-research-services/guidelines/gtg52/ [Accessed 25th January 2017,].

Royal College of Obstetricians and Gynaecologists & Royal College of Midwives. 2006. Immersion in water during labour and birth, Joint statement No.1., 10. Available: https://waterbirth.org/rcog-rcm-joint-statement/ [Accessed 28th December 2015].

Ruiz, J., Mintzer, M. & Leipzig, R. 2006. The impact of e-learning in medical education. [Online]. Academic medicine, 81(3), pp.207-212. . Available: http://journals.lww.com/academicmedicine/abstract/2006/03000/the_impact_of_e_learning_in_medical_education.2.aspx. [Accessed 28th January 2017].

Schorn, M. 2010. Measurement of blood loss: review of the literature. Journal of Midwifery and Women's Health, 55, 20-27.

Sukprasert, M., Chokanasiri W, Ayudhya Ni, Promsonthi P & O-Prasertsawat P 2006. Increase accuracy of visual estimation of blood from education programme. J Med Assoc Thai 89, S54-59.

Toledo, P., Eosakul S, Goetz K, Wong C & Grobman W 2012. Decay in Blood Loss Estimation Skills After Web-Based Didactic Training. Simulation in Healthcare. Journal of the Society for Simulation in Healthcare., 7, 18-21.

Toledo, P., Mccarthy Rj, Burke Ca, Goetz, K., Wong, C., William, A. & Grobman, M. 2010. The effect of live and web-based education on the accuracy of blood-loss estimation in simulated obstetric scenarios. Am J Obstet Gynecol 202, 400.e1-5.

Walsh, D., Spiby H, Grigg Cp, Dodwell M, Mccourt C, Culley L, Bishop S, Wilkinson J, Coleby D, Pacanowski L, Thornton J & Byers S 2018. Mapping midwifery and obstetric units in England. Midwifery, 56, 9-16.

Which? Birth Choice. 2017. Which? Available: http://www.which.co.uk/birth-choice/ [Accessed 2nd November 2017].

World Health Organisation. 2009. WHO guidelines for the management of postpartum haemorrhage and retained placenta. [Online]. Geneva, Switzerland: WHO. Available: http://apps.who.int/iris/bitstream/handle/10665/44171/9789241598514_eng.pdf;jsessionid=8877679628DBE74CB5C71BDDDA83053A?sequence=1 [Accessed January 2017].

World Health Organisation & Unicef. 2018. Countdown to 2030: Maternal, Newborn and Child Surviva [Online]. Geneva: WHO. Available: http://countdown2030.org/ [Accessed 30th August 2018]

World Health Organistion. 2018. Maternal mortality [Online]. Geneva: WHO. Available: http://www.who.int/news-room/fact-sheets/detail/maternal-mortality [Accessed 30th August 2018].

Yoong, W., Karavolos S, Damodaram M, Madgwick K, Milestone N, Al-Habib A, Fakokunde A & Okolo S 2010. Observer accuracy and reproducibility of visual estimation of blood loss in obstetrics: how accurate and consistent are health-care professionals? Archives of Gynecology and Obstetrics, 281, 207-213.

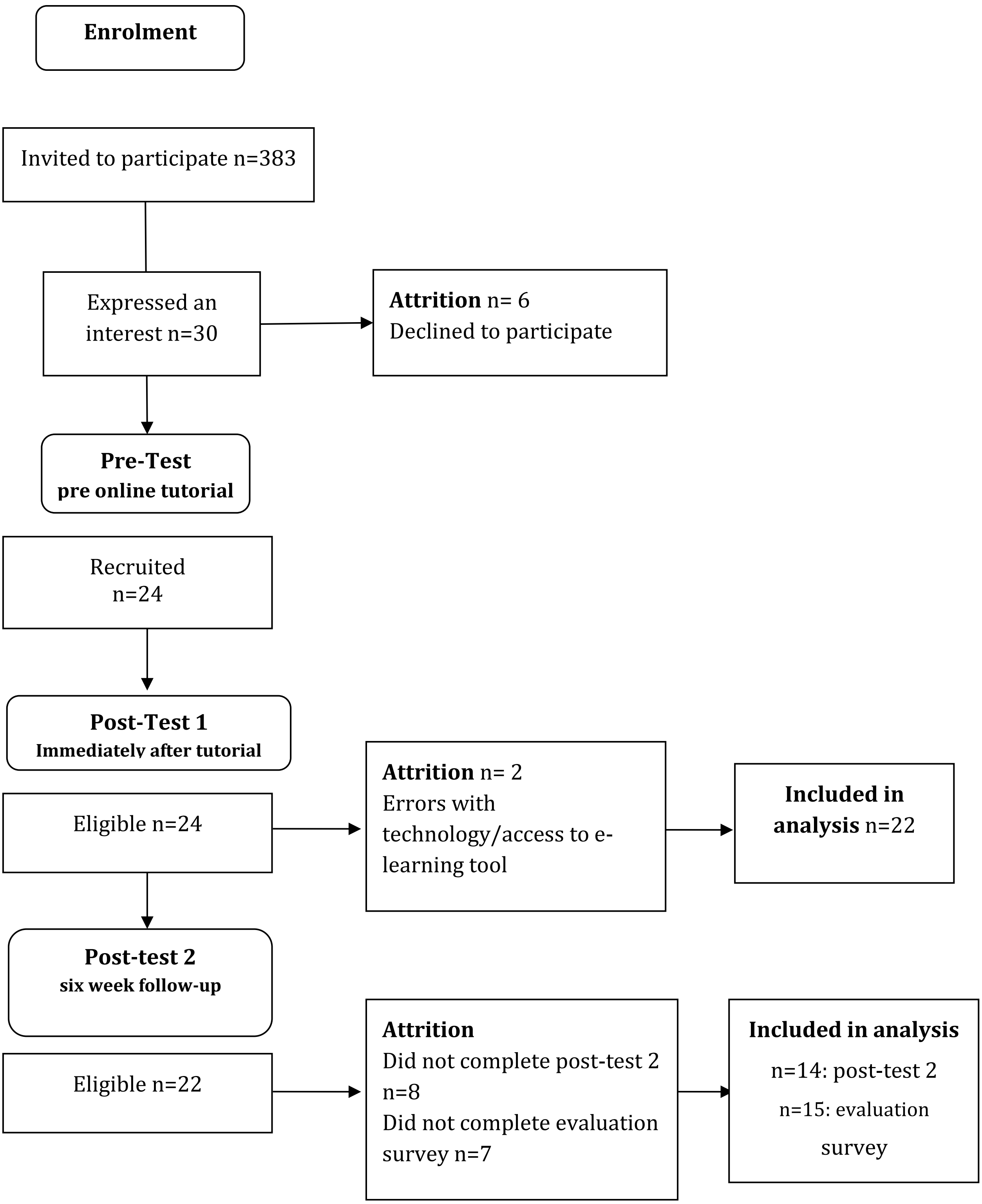

Figure 1 Flow diagram showing the participants included in the three parts of the study.

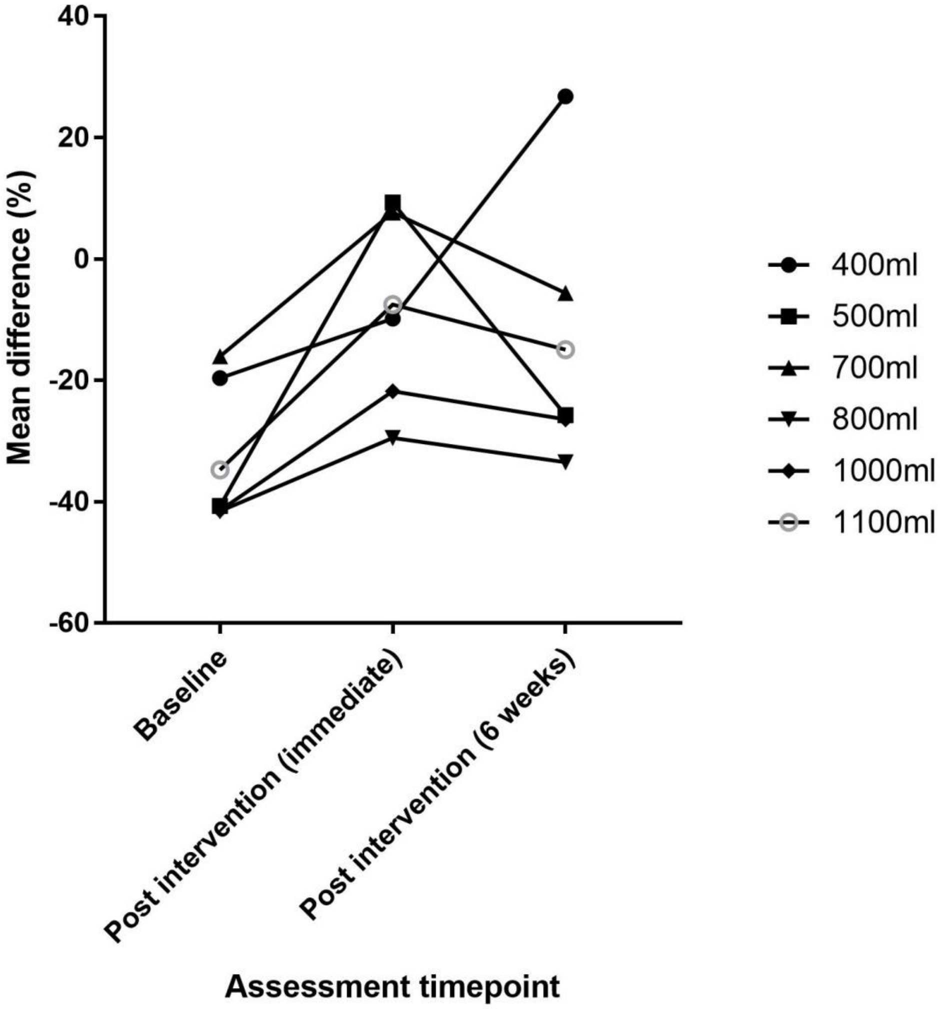

Figure 2 *Mean differences (%) between actual and estimated blood loss for each blood volume for the midwives with data for all three timepoints (n=14). Note 0% represents no difference between actual blood volume and estimated blood volume.*

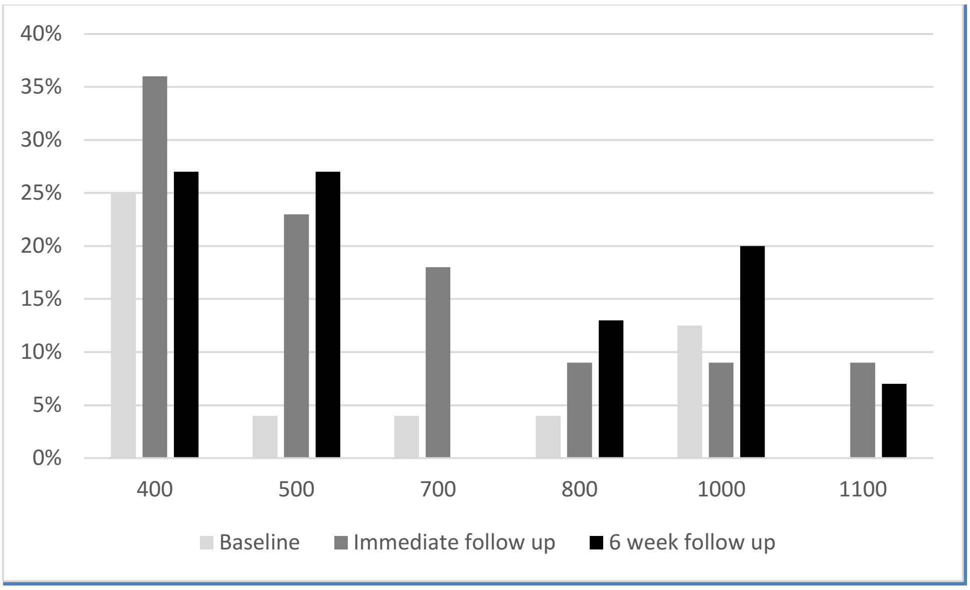

Figure 3 Proportions of correct estimates pre-test, post-test 1, post-test 2

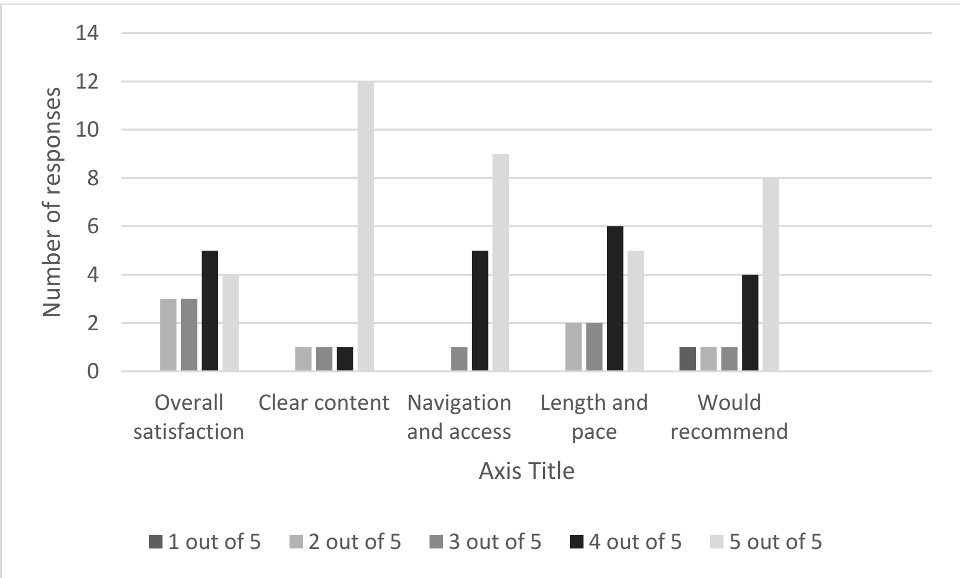

Figure 4 Summary of participants' responses to evaluation of online learning tool (Rating of 1-5 signifying favourable evaluation)