Developing best practices teaching procedures for skinfold assessment: observational examination using the Think Aloud method

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Holmstrup ME, Verba SD, Lynn JS. Developing best practices teaching procedures for skinfold assessment: observational examination using the Think Aloud method. *Adv Physiol Educ* 39: 283–287, 2015; doi:10.1152/advan.00044.2015.—Skinfold assessment is valid and economical; however, it has a steep learning curve, and many programs only include one exposure to the technique. Increasing the number of exposures to skinfold assessment within an undergraduate curriculum would likely increase skill proficiency. The present study combined observational and Think Aloud methodologies to quantify procedural and cognitive characteristics of skinfold assessment. It was hypothesized that *1*) increased curricular exposure to skinfold assessment would improve proficiency and *2*) the combination of an observational and Think Aloud analysis would provide quantifiable areas of emphasis for instructing skinfold assessment. Seventy-five undergraduates with varied curricular exposure performed a seven-site skinfold assessment on a test subject while expressing their thoughts aloud. A trained practitioner recorded procedural observations, with transcripts generated from audio recordings to capture cognitive information. Skinfold measurements were compared with a criterion value, and bias scores were generated. Participants whose total bias fell within ±3.5% of the criterion value were proficient, with the remainder nonproficient. An independent-samples *t*-test was used to compare procedural and cognitive observations across experience and proficiency groups. Additional curricular exposure improved performance of skinfold assessment in areas such as the measurement of specific sites (e.g., chest, abdomen, and thigh) and procedural (e.g., landmark identification) and cognitive skills (e.g., complete site explanation). Furthermore, the Think Aloud method is a valuable tool for determining curricular strengths and weaknesses with skinfold assessment and as a pedagogical tool for individual instruction and feedback in the classroom.

think aloud; skinfold; pedagogy

BODY COMPOSITION is one of the five health-related physical fitness components highlighted by the American College of Sports Medicine (ACSM) and is an important factor in chronic disease risk evaluation (1, 12). The assessment of body composition can provide the health practitioner with valuable information to educate and inform clients about chronic disease risk, evaluate the outcomes of diet and exercise intervention, and track musculoskeletal changes concomitant with aging (1, 12).

The skinfold method is widely used in the fields of exercise science and clinical nutrition (5), likely due to the convenience granted by the relatively low cost and portability of calipers and the short testing time. The use of skinfold assessment to estimate body fat percentage has been shown to be valid compared with estimates generated from hydrostatic weighing (4). When performed correctly, the SE of the estimate when comparing skinfold assessment with hydrostatic weighing is ±3.5% (5), which is accepted as a tradeoff for the economy and practicality of skinfold assessment. However, when skinfold assessment is not executed properly, the potential error is inflated, making the resulting data and findings misleading and not applicable.

The skill level of the skinfold technician can have a large impact on reliability and accuracy (1, 9, 12). Previous studies have attempted to quantify various aspects of the complex procedure of skinfold assessment, including the impact of technical precision in landmark identification (7, 9, 14), and the choice of skinfold calipers and equations (9). Landmark identification aside, several critical techniques regarding caliper use must be mastered to generate reproducible skinfold values. These skills include, but are not limited to, proper caliper alignment and placement on the fold (perpendicular, halfway between the base and crest of fold; Fig. 1), measurement duration (1- to 2-s placement), and the rotation of sites measured during the assessment (12). The comprehensive analysis of all of the technical aspects of skinfold assessment and how these relate to proficiency remains to be fully evaluated.

In defense of the complex nature and multiple components of skinfold assessment, well-regarded teaching sources recommend that an individual invest a "significant amount of practice" (often quantified as 50–100 tests performed) under the supervision of experienced technicians to develop proficiency using the method (5). As extensive practice of the process of skinfold assessment is necessary to develop a sound practitioner, it is obvious that an increase in curricular exposure, or the number of sessions and opportunities within a health sciences curriculum to develop and practice skinfold technique, should lead to improved performance. Furthermore, the appropriate prompting and teaching cues to use during these supervised exposures are likely just as important as the amount of time dedicated to skill development but may not be as well understood.

The performance of a complex, multifaceted task is accompanied by cognitive processes that cannot be quantified or qualified through direct observation alone, and the performance of skinfold assessment is an example of this type of task. Fortunately, the Think Aloud method allows insights into the thought processes that occur during the completion of a task (3, 6, 13). The Think Aloud method requires the participant to verbalize their thoughts while performing a given task, allowing the analysis of both individual reasoning processes and metacognition. When groups of participants with different experience levels are studied, the Think Aloud method can reveal insights into the cognitive strategies used by proficient

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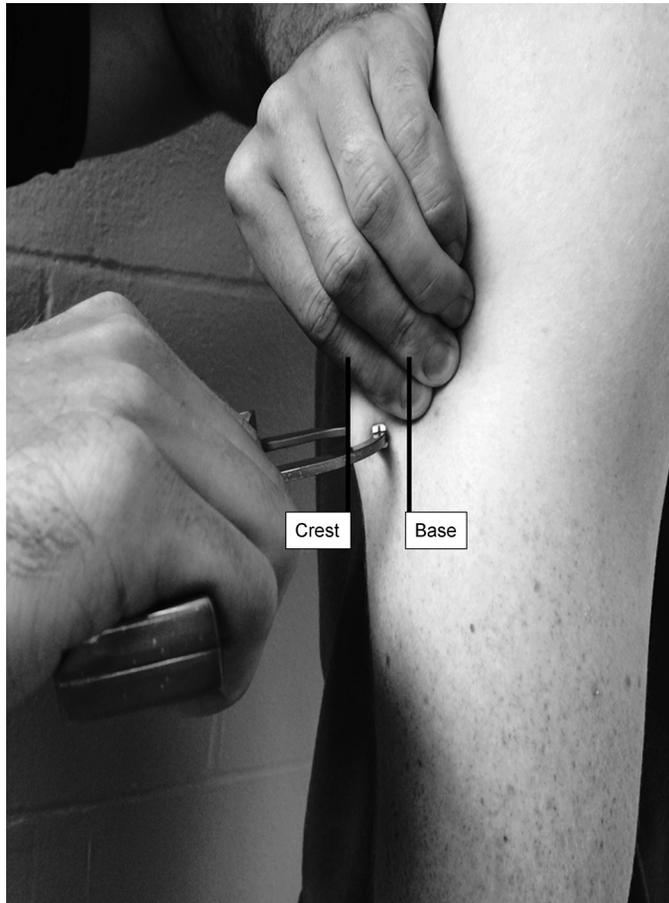
Fig. 1. Proper measurement technique of the triceps skinfold site. Procedural aspects of interest include the following: perpendicular alignment of the calipers, grasp placement above the site, maintenance of grasp/confident grasp during measurement, proper direction of the fold (vertical), and placement of the calipers halfway on the fold (midway between the base and crest).

task practitioners (6) and pitfalls to avoid that may emerge from the findings regarding nonproficient practitioners.

When used in a complementary fashion, observational study and the Think Aloud method can be used as a powerful tool to dissect the performance of a complex task. The understanding garnered from these analyses can be used to develop best practices teaching techniques (to capitalize on limited class sessions intended to develop proficiency) and guide practitioners toward successful strategies for continually improving

performance. Therefore, the aim of the present study was to assess the effects of additional curricular exposure on proficiency with skinfold assessment and to characterize the differences between groups in the observed techniques and cognitive processes reported through the Think Aloud method in individuals with varying experience and proficiency with skinfold assessment. It was hypothesized that additional curricular exposure would lead to improvements in skinfold assessment proficiency. Furthermore, it was hypothesized the use of a combined observational and Think Aloud analysis of skinfold assessment would allow a better understanding of how distinct areas of technical and cognitive process contribute toward skinfold assessment proficiency and provide a framework for best practices recommendations for improving the development of this skill within a health sciences curriculum.

MATERIALS AND METHODS

Study participants. This study was approved by the Institutional Review Board of Slippery Rock University, and participants provided informed consent before data collection. Students from the Exercise Science Program at Slippery Rock University were recruited for participation based on course enrollment. Sophomore students in the Exercise Physiology course, after performing an introductory module on skinfold techniques in the laboratory ($\sim$2 h of exposure, including orientation and hands-on practice), were recruited as a novice cohort. Additionally, senior-level students who had completed the Fitness Assessment course (additional 5 h of supervised skinfold assessment, up to 25 h of out-of-class practice sessions in the open laboratory, and a qualifying practical examination) were recruited as an experienced cohort. This selection of discrete participant groups was used to produce some gradation in the proficiency level between novice and experienced cohorts.

Study procedures. On the day of data collection, participants reported to the Exercise Science Research Laboratory, where they completed two sample exercises (a math problem and an anagram; see Table 1) as part of a consistent, scripted introduction based on previous work (3, 6) to become familiar with the expectations of the Think Aloud method. The participant was required to verbalize all of their thoughts while completing these sample tasks. Individuals were prompted to continue "thinking aloud" if they became silent. The correct answers to the exercises were less important than the extent to which the participant verbalized their thoughts. After this orientation, participants were asked if they had any specific questions regarding the use of the Think Aloud method before the following additional scripted notice was read:

> Now I would like you to perform a 7-site skinfold examination on the subject. I will present you with the subject, and

Table 1. *Think Aloud script*

"In this experiment, we are interested in what you say to yourself as you perform some tasks that we give to you. To do this, we will ask you to *talk aloud* as you work on the problems. What I mean by talk aloud is that I want you to say out loud *everything* that you say to yourself silently. Just act as if you are alone in the room speaking to yourself. If you are silent for any length of time I will remind you to keep talking aloud. Do you understand what I want you to do?"
"Good! Before we turn to the real experiment, we will start with a couple of practice problems. I want you to talk aloud while you do these problems. First, I will ask you to multiply two numbers in your head."
"So *talk aloud* as you multiply 24 times 34!"
"Good!"
"Now, I would like you to solve an anagram. I will show you a card with scrambled letters. It is your task to find an English word that consists of all the presented letters. For example, if the scrambled letters are KORO, you may see that these letters spell the word ROOK. Any questions? Please *talk aloud* while you solve the following anagram!"
"NPEPHA = HAPPEN"
"Good!"

you will perform this task to the best of your ability. Please *talk aloud* as you perform this skinfold assessment.

Participants then performed a seven-site, Jackson Pollock (triceps, subscapular, chest, midaxillary, suprailliac, abdominal, and thigh) skinfold assessment with a dedicated set of skinfold calipers (Lange, Beta Technology, Santa Cruz, CA) on the consistent test subject (female subject, 21 yr old). During this assessment, each participant used the Think Aloud method, reporting out loud all of the thoughts, steps, and procedures that they were contemplating and performing. When a participant became silent, a researcher would remind them to continue to express their thoughts out loud. Participants were observed during the administration of the skinfold assessment by two trained practitioners, with detailed notes taken regarding the techniques used (rubric; Table 2), and a digital audio file of the concurrent Think Aloud exercise was recorded. Subjects were required to take blinded, duplicate measures of each of the seven skinfold sites.

Data analysis. For each participant, the two measurements of each skinfold site were compared with each other to establish reliability, with score variance of less than or equal to ± 2 mm considered acceptable (1). All of the skinfold sites were first measured by an expert, known as a criterion anthropometrist, to establish a standard with which to compare participant measures. To establish the accuracy of each participant at each skinfold site, the absolute value for the difference between the criterion antrhopometrist's measure for the site and average of that participant's measure for the same site were calaculated as a bias score. The bias score was calculated as follows (for the triceps): bias score triceps = |participant measure − criterion measure|.

Calculated bias scores for each of the seven skinfold sites were then added together to create a total bias score for each participant. Individuals whose total bias score was within 22 mm of the combined value measured by the criterion anthropometrist for all seven sites ($\pm 3.5\%$ body fat) were deemed accurate. Participants who were deemed both reliable and accurate were considered proficient, with all others considered nonproficient. An independent-samples *t*-test was used to compare procedural observations between novice and experienced groups as well as proficient and nonproficient groups. An a priori α-level of 0.05 was established to reflect significant differences between these groups.

All of the digital audio recordings from the Think Aloud exercise (recorded during the completion of the skinfold assessment) were converted into written transcripts. Two investigators used a small sample of the Think Aloud transcripts ($n = 6$) to inductively develop a coding rubric to classify the strategies used by participants during the skinfold assessment exercise (6). After the development of this rubric, the investigators independently coded an additional small set of Think Aloud transcripts ($n = 6$) using this new rubric. Upon achieving an intercoder agreement coefficient of $>85\%$ (6), small changes were made for clarification, and the remaining transcripts were then coded by an independent investigator. Comparisons in the procedures, thoughts, and characteristics between participants deemed proficient and nonproficient were formulated and reported qualitatively.

RESULTS

Subject characteristics. Seventy-five subjects were recruited to, and completed all of the requirements for, the present study. Thirty-seven of these participants were considered as novices (sophomore, Exercise Physiology course), whereas thirty-eight of these participants were considered as experienced (senior, Fitness Assessment course). The criterion anthropometrist's measurements revealed that the test subject was ~22% body fat.

Sixty-two of the participants successfully measured all seven skinfold sites and were considered for further examination.

Thirteen individuals from the novice group were excluded from the proficiency classification as they failed to locate and measure all seven skinfold sites. Inclusion of their data would have skewed categorization, as a total bias score for fewer than seven sites would have been more likely to fall beneath the established 22-mm cutoff and classify the participant as accurate. Each participant in the experienced cohort was able to identify all seven sites. In line with our recruiting strategy, 23 of 25 proficient participants came from the experienced cohort. Furthermore, 24 of 37 nonproficient testers came from the novice group, with an additional 13 nonproficient testers from the experienced group.

Table 2. *Rubric for the evaluation of the skinfold technique*

Calibrate caliper: Y/N						Right side: Y/N	
Site Location							
Correct?		Measured?		Landmark used?		Grasp Above Site?	
Trial 1	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*
Triceps							
Subscapular							
Chest							
Midaxillary							
Suprailliac							
Abdomen							
Thigh							
Grasp Technique							
Proper fold direction?		Hand placement?		"Confident" grasp?			
Trial 1	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*		
Triceps							
Subscapular							
Chest							
Midaxillary							
Suprailliac							
Abdomen							
Thigh							
Use of Caliper							
Halfway on fold?		1- to 2-s placement?		Perpendicular to fold?			
Trial 1	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*		
Triceps							
Subscapular							
Chest							
Midaxillary							
Suprailliac							
Abdomen							
Thigh							
Fully release Caliper?		Grasp maintained?		Rotate through?			
Trial 1	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*		
Triceps							
Subscapular							
Chest							
Midaxillary							
Suprailliac							
Abdomen							
Thigh							

Comparison of skinfold techniques. Additional curricular exposure (completion of the Fitness Assessment course) resulted in significant improvements across all areas of procedural proficiency measured in our study (Table 3), with the exception of "calibration of the skinfold calipers," which was performed by just under 20% of both the novice and experienced groups.

The proficient group had a mean bias score that was significantly less than the nonproficient group on the chest (2.6 ± 1.7 vs. 5.7 ± 2.8 mm), abdomen (2.0 ± 1.6 vs. 4.4 ± 2.5 mm), and thigh skinfold sites (1.7 ± 1.2 vs. 4.7 ± 2.7 mm). Both the proficient and nonproficient groups had a very large mean deviation from the criterion anthropometrist's measure on the suprailiac site (9.5 ± 1.7 vs. 10.7 ± 3.2 mm), respectively.

Observational analysis revealed that a significantly greater portion of the proficient subjects measured distances between landmarks correctly (88.0% vs. 54.1%), correctly used anatomic landmarks for site identification (88.0% vs. 43.2%), grasped all skinfolds in the proper direction (96.0% vs. 73.0%), used a confident, four-finger fold grasp (88.0% vs. 40.5%), and maintained their grasp for 1–2 s (92.0% vs. 67.6%). Interestingly, only 50% of the experienced students placed the calipers halfway between the base and crest of the skinfold, a potential source of error (Fig. 1).

Think Aloud analysis. Proficient participants were significantly more likely to mention grasping above the skinfold site (44.0% vs. 18.9%) and measuring halfway between the base/crest of the skinfold site (44.0% vs. 16.2%) during the recording of their measurement. Likewise, these proficient individuals paid more attention to detail in mentioning all of the components of a complete site explanation (e.g., all proper bony landmarks, measurement details, etc.) for the chest, midaxillary, suprailiac, and abdominal skinfold sites.

DISCUSSION

Exercise science, clinical nutrition, and associated allied health programs may have varying degrees of curricular exposure and hands-on training time dedicated to the practice of skinfold assessment. Often, this experience may consist of one laboratory session in a foundation course where students practice these techniques. As hypothesized, the present study demonstrated increased curricular exposure, amounting to the addition of 5 h of supervised instruction, the opportunity for out-of-class practice sessions in an open laboratory setting, and a qualifying practical exam improved proficiency in skinfold assessment. The majority of proficient participants were discovered from the experienced individuals within our cohort, and these experienced individuals demonstrated greater familiarity with the multiple procedural variables that comprise skinfold assessment than their novice counterparts.

Among these procedural variables, of which landmark identification has been the most widely reported and emphasized (7, 9, 14), improvements were shown in all aspects, save caliper calibration, which participants may have assumed. Five of the reported skinfold procedures, outlined below, could contribute to the overall proficiency of landmark identification and were greatly improved with additional curricular exposure. Experienced individuals performed their measurements on the right side of the body (100%) and with each of the duplicate, seven-site measurements in the proper direction (100%, e.g., vertical or diagonal fold direction). These were 25% and 44% improvements over the novice participants, who represented students exposed to curricula with a single, supervised exposure to skinfold assessment. Likewise, deliberate landmark use (89%, 64% improvement), measurement of site location with a measuring tape (87%, 37% improvement), and correct positioning and use of the tape (82%, 40% improvement) were demonstrated with greater proficiency in the experienced cohort.

When the novice and experienced cohort were combined and each individual's reliability and accuracy were determined to classify based on proficiency, several expected findings emerged in line with our second hypothesis. The combination of an observational and Think Aloud analysis allowed us to pinpoint critical areas of interest in general skinfold assessment and, potentially of more importance, within our curriculum in relation to skinfold assessment. Subsequent analyses in other exercise science or clinical nutrition curricula could reveal very different areas of focus, depending on the guidelines or texts used, instructor training and previous experience, or the educational setting.

In our curriculum, a procedural aspect of particular interest moving forward will be the placement of the skinfold calipers halfway on the base and crest of the skinfold (Fig. 1). Only 50% of the experienced cohort demonstrated proficiency with this component of technique (14% in the novice cohort), which is emphasized in ACSM standards (1). It is likely that mastery of caliper depth placement during measurement could further improve reliability and accuracy in the experienced individuals. Similarly, proficient testers were found to be more accurate (closer to criterion anthropometrist) than their nonproficient counterparts at several particular skinfold measurement sites, including the chest, abdomen, and thigh. Armed with this information, an instructor charged with teaching skinfold assessment in an introductory setting could pay particular attention to caliper depth and landmark identification associated with the chest, abdomen, and thigh sites to highlight areas that have been shown to directly relate to improved proficiency.

Table 3. *Procedural proficiency percentage and curricular exposure*

	Novice Cohort	Experienced Cohort	Difference
Perpendicular?	88.89	100.00	11.11*
Rotate through?	88.89	100.00	11.11*
Grasp maintained?	86.11	100.00	13.89*
Right side?	75.00	100.00	25.00*
Above site?	72.22	100.00	27.78*
Hand placement?	58.33	100.00	41.67*
Proper direction?	55.56	100.00	44.44*
Fully release?	83.33	97.37	14.04*
1–2 s?	58.33	89.47	31.14*
Landmark used?	25.00	89.47	64.47*
Confident grasp?[a]	19.44	89.47	70.03*
Measured?[b]	50.00	86.84	36.84*
Correctly?[c]	41.67	81.58	39.91*
Halfway on fold?	13.89	50.00	36.11*
Calibrate?	16.67	18.42	1.75

*Significantly greater percentage than 200-level ($P < 0.05$). [a]Determined by the consistent test subject. [b]When measurement was required, participant used a measuring tape. [c]When measurement (with measuring tape) was required, participant did so correctly.

Not all of the findings of this study demonstrated improved proficiency with experience, however, as both the proficient and nonproficient testers averaged an ~10-mm discrepancy from the criterion measure on the suprailiac site. In this instance, a previously unknown phenomenon was noted during the observed skill practice, which could lead to further investigation. Briefly, while the suprailiac site used by the ACSM correctly aligns with the site described in the reference materials for the original equation, it is likely that improved clarity regarding this site (including the photo reference) would be helpful (1). The International Standards for Anthropometric Assessment (8) distinguish that two separate sites have been previously referred to as the suprailiac, the "iliac crest" site as defined by Durnin and Wormersly (2) and the "supraspinale" as defined by Parnell (11). In the absence of a carefully designed observational protocol, this difference may have gone unnoticed.

An exploration of the Think Aloud transcripts also yielded several important considerations that could potentially impact educational practices in teaching proficiency in skinfold assessment. An improved attention to detail was mentioned in the location of several of the skinfold sites (chest, midaxillary, suprailiac, and abdominal) when proficient testers were performing the seven-site skinfold test. In line with the observational findings (wherein the chest and abdominal sites were located with greater skill in the proficient cohort), it is possible that the process of "thinking aloud" may have improved some of the procedural aspects measured. In fact, tying language expression to the completion of a complex task may allow an individual to cue upcoming actions and reduce errors (10).

Thus, the simple act of presenting the Think Aloud methodology of "saying everything out loud that you are thinking to yourself" during task completion may be a powerful teaching tool in the initial stages of skill development related to skinfold assessment. Instructors and peers could provide immediate feedback regarding areas where clarity, accuracy, and precision were lacking in both expressed thoughts and observed procedures. This in-class process could be especially useful in the complex process of precise landmark identification. Likewise, additional attention to detail in measurement and grasping techniques demonstrated by the proficient testers could be highlighted and evaluated as components of a Think Aloud exercise to potentially enhance skill acquisition.

As this was an exploratory study, it is important to point out that additional procedural steps may have been neglected by the observers and in the generation of the procedural rubric, although an honest effort was made to align the procedural rubric to published procedural steps (1, 5) related to the specifics of landmark identification and details of grasping and measurement technique. Limitations to the present study may include bias toward nuances in measurement technique acquired by the observers due to their previous instruction and experience. Also, the use of a normal-weight female subject in this study may not reflect all of the potential challenges with skinfold assessment, and more work should be done quantifying skill development in the assessment of overweight and obese individuals. Furthermore, adherence to the tenets of the Think Aloud protocol, especially voicing all of the thoughts that come to mind, may have been more limited in the novice (and by default nonproficient) cohort than the experienced cohort.

In conclusion, a single exposure in a laboratory course was inadequate in training students to accurately assess body composition using skinfolds, but additional exposure of 5 h with a practical examination and 25 h of available practice time substantially improved reliability and accuracy. Moreover, the Think Aloud method may be a valuable pedagogical strategy for exposing strengths and weaknesses in skinfold technique across the curriculum and improving this technique in individual students within a classroom setting.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: M.E.H. and S.D.V. conception and design of research; M.E.H. and S.D.V. performed experiments; M.E.H., S.D.V., and J.S.L. analyzed data; M.E.H., S.D.V., and J.S.L. interpreted results of experiments; M.E.H. prepared figures; M.E.H. drafted manuscript; M.E.H., S.D.V., and J.S.L. edited and revised manuscript; M.E.H., S.D.V., and J.S.L. approved final version of manuscript.

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