

Evaluation of a Gait Assessment Module Using 3D Motion Capture Technology

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Background: Gait analysis is the study of human locomotion. In massage therapy, this observation is part of an assessment process that informs treatment planning. Massage therapy students must apply the theory of gait assessment to simulated patients. At Humber College, the gait assessment module traditionally consists of a textbook reading and a three-hour, in-class session in which students perform gait assessment on each other. In 2015, Humber College acquired a three-dimensional motion capture system.

Purpose: The purpose was to evaluate the use of 3D motion capture in a gait assessment module compared to the traditional gait assessment module.

Participants: Semester 2 massage therapy students who were enrolled in Massage Theory 2 (n = 38).

Research Design: Quasi-experimental, wait-list comparison study.

Intervention: The intervention group participated in an in-class session with a Qualisys motion capture system.

Main Outcome Measure(s): The outcomes included knowledge and application of gait assessment theory as measured by quizzes, and students' satisfaction as measured through a questionnaire.

Results: There were no statistically significant differences in baseline and post-module knowledge between both groups (pre-module: $p = .46$; post-module: $p = .63$). There was also no difference between groups on the final application question ($p = .13$). The intervention group enjoyed the in-class session because they could visualize the content, whereas the comparison group enjoyed the interactivity of the session. The intervention group recommended adding the assessment of gait on their classmates to their experience. Both groups noted more time was needed for the gait assessment module.

Conclusions: Based on the results of this study, it is recommended that the gait assessment module combine both the traditional in-class session and the 3D motion capture system.

KEY WORDS: educational research; technology; gait assessment; massage therapy students

INTRODUCTION

Gait analysis is the study of human locomotion. The observation and assessment of gait is an important tool for health care providers, primarily those in rehabilitation, to determine areas of dysfunction.⁽¹⁾ In massage therapy, this observation is part of a larger assessment process that informs a treatment plan for the individual. The gait assessment itself ranges in complexity. For the average practitioner, gait assessment may be the simple observation of a patient as he or she walks to the treatment room. Others use a complex approach combining observation with technology, such as tablet applications that video record gait, force measurement plates, or motion capture systems. Regardless of the combination of observation and technology, practitioners observe cadence, step and stride length, step width, and overall ease of movement.⁽²⁾ Normal and abnormal findings are noted.

Humber College's massage therapy program, in Toronto, Ontario, introduces gait assessment in the second semester of the six-semester program. At that point in the program, students have explored the anatomy of the lower limb and have introductory knowledge of joint movements. They have a good understanding of the assessment process and have conducted postural assessments that utilize observational skills similar to those used in gait assessment. The gait assessment module (GAM) is intended to be an introduction and is continued in future semesters when lower limb orthopedic and neurologic conditions are discussed.

The module traditionally consists of reading the gait assessment chapter from the course textbook, McGee's *Orthopedic Physical Assessment*,⁽²⁾ and an in-class session. During the three-hour in-class session, students discuss the theory of gait assessment and confirm parameters of normal gait. They then assess each other. As one student walks across craft paper taped to the floor, the other student tries to mark step length and width. They also observe for cadence and overall ease of movement. Students share their findings and practice recording their observations. Sometimes, videos of common abnormal gaits are used to reinforce theories and observations.

In spring 2015, Humber College acquired a three-dimensional motion capture system (3D MCS), which is used to digitize the position of reflective markers for kinematic analysis. The Qualisys motion capture system⁽³⁾ is a passive marker 3D kinematic system with an integrated, force-plate instrumented treadmill.⁽⁴⁾ Although normally used for quantitative assessment, the advantage of using this technology for qualitative assessment is that the user can isolate biomechanical movement patterns, as only the wire frame or skeletal representation of the subject appears on-screen.

In the literature, 3D MCSs have been used as a data collection tool to measure kinematics. In child health and development, the technology is used to measure reach-to-grasp tasks in children with autism,⁽⁵⁾ development of hammering in toddlers,⁽⁶⁾ and social interactions between a child and his caregiver.⁽⁷⁾ The same is seen in studies of the military,⁽⁸⁾ athletes,⁽⁹⁾ and clinical patients with conditions, such as Parkinson's disease.⁽¹⁰⁾

Other uses for 3D MCSs are as part of an intervention. A few studies explore its use in training programs, where the user attempts to learn a task or skill, such as dancing.⁽¹¹⁻¹³⁾ One example was also found in education.⁽¹⁴⁾ That study used the technology as part of a learning intervention; capture data and video were used in the creation and use of clinical case studies. Kinesiology students used the data and videos to inform their critical thinking process and to develop a solution. To date, the use of 3D MCS as a pedagogical tool for enhancing qualitative gait assessment skills has not been investigated.

Research Question

The research question was: "For Semester 2 massage therapy students, does the integration of 3D motion capture impact application of gait assessment and student satisfaction with the gait assessment module compared to the traditional educational module?" We hypothesized that the introduction of this novel technology would help the intervention group apply gait assessment theories better than the comparison group.

METHODS

A quasi-experimental wait-list comparison study was used wherein, after completing a common online module, one section of Semester 2 massage therapy students participated in the intervention, and the other participated in the comparison GAM. Following the study, an option to participate in the intervention was made available to the comparison group. Humber College's Research Ethics Board granted approval for this project.

Sample and Recruitment

The research assistant (RA) invited students who were enrolled in Massage Theory 2 ($n = 38$) to participate. She reviewed the information sheet and answered questions. Students could withdraw at any time by contacting the RA. As one of the investigators was the program coordinator (AB) and another the course instructor (PB), this process reduced the possibility of coercion.

Comparison and Intervention Gait Assessment Modules

It was not ethical to randomize participants to either the intervention or comparison because the participants choose their course sections at the beginning of the semester. Also, the room housing the MCS was not available during the second section's class time. That scheduling restriction determined which group received the intervention versus the comparison module. Both groups completed an online module, which was available the week before the in-class sessions through the learning management system; it consisted of a video and a series of questions regarding the basic elements of gait and potential abnormal findings.

The comparison group participated in an in-class session in the massage therapy lab, representative of the GAM traditionally used in the program. It consisted of an instructor-led PowerPoint presentation reviewing basic concepts. The students also observed the gait of one of their classmates. With the assistance of the instructor, the students made observations consistent with a standard gait assessment, then partnered up to conduct a more thorough gait assessment on each other.

The intervention group participated in an in-class session in a fitness and health promotion lab where an eight-camera Qualisys MCS was set up. It began with the same instructor-led review. Then, two students volunteered to be the subjects for the gait assessment. Three students attached 35 reflective markers (1 cm diameter) at anatomical landmarks using a modified Helen-Hayes marker set. The subject performed one walking and one running trial (subject-selected speed), which were captured and post-processed in Qualisys Track Manager⁽¹⁵⁾ at a sampling rate of 60 Hz. A skeletal representation of the trial was generated in Visual 3D Pro v6.⁽¹⁶⁾ The students viewed the walking and running trials in real time, slow motion, and from multiple angles. As the basic elements of the subject's gait were observed and discussed, the students determined the speed and angle of playback. No specific certification is needed to operate the Qualisys 3D motion capture system. The amount of training required to operate 3D motion capture systems varies according to the chosen system. The operator in this study (LK) had a PhD in Biomechanics.

Data Collection

Data were collected at three points during the study. First, participants' baseline knowledge of gait assessment was tested prior to the module, using an assessment developed from the textbook.⁽²⁾ A second knowledge assessment was administered at the end of the online module, using questions matched to the first.

Two weeks following the in-class session, a third assessment was administered along with a questionnaire. The third assessment asked students to watch a video of an individual's gait and conduct a visual (qualitative) assessment, noting normal and abnormal findings in both stance and swing phase for the related muscles and joints. Also, a nine-statement questionnaire collected students' satisfaction and experience with the gait assessment module. Students indicated to what extent they agreed with the statements on a seven-item Likert scale, from strongly agree to strongly disagree (i.e., "The format of the in-class session for gait assessment fit with my learning style."). There were three open-ended questions that asked students what they enjoyed, what they would change, and for any additional comments.

Data Analysis

Following the completion of the data collection, one of the researchers (AB) graded all of the short-answer questions using the learning management software (LMS). This allowed for the questions to be marked while maintaining participant anonymity. The data from each questionnaire were downloaded from the LMS and saved in an MS Excel spreadsheet. Data were removed for participants who only completed one of the pre-module or post-module questionnaires or who did not consent to participate in the study, resulting in the removal of two participants' data, one from each group.

Paired *t* tests evaluated the difference between the pre-online and post-online module questionnaire scores within the groups. Unpaired *t* tests determined whether any differences existed between the groups. Frequency distributions were calculated to describe the data regarding students' experiences.

RESULTS

Of the 38 students enrolled in the course, 36 students consented to participate. Two students did not complete the first two knowledge quizzes. Their data were removed for the first two quizzes, resulting in 17 participants in each group for the related analyses. Two different students failed to complete the third assessment and questionnaire, resulting in 16 participants in the intervention group and 18 participants in the comparison group for the analysis of the final assessment and questionnaire.

Knowledge and Application Quizzes

On the pre-online module questionnaire, the intervention group had a mean score of 3.6/10 (SD \pm 0.4) while the comparison group had a mean score of 4.0/10 (SD \pm 0.4). There was no statistically significant difference between the groups in the first questionnaire ($p = .46$).

On the post-online module questionnaire, the intervention group scored an average of 4.4/10 (SD \pm 0.5) and the comparison group scored an average of 4.1/10 (SD \pm 0.4). Again, there was no statistically significant difference between the two groups ($p = .63$). The paired *t* tests showed that there was also no statistically significant difference within the groups between the pre-module and post-module questionnaires (intervention group: $p = .14$; comparison group: $p = .83$).

Thirty-four students participated in the final assessment. On the gait analysis question, the intervention group scored 5.4/10 (SD \pm 0.6) and the comparison group scored 4.1/10 (SD \pm 0.5). No statistically significant difference was seen ($p = .13$).

Questionnaire

For the statement, "The online portion of the gait assessment module helped me to learn basic concepts related to gait assessment", 37.5% of participants in the intervention group agreed or strongly agreed. While 18.8% slightly agreed, 25% neither agreed nor disagreed, and 18.8% disagreed to some extent with this statement. In the comparison group, 27.8% of participants agreed or strongly agreed, 55.6% slightly agreed, and 16.7% neither agreed nor disagreed with this statement.

In the intervention group, 56.3% agreed or strongly agreed with the statement "The textbook (McGee) helped me to learn basic concepts related to gait assessment." In addition, 18.8% slightly agreed, 12.5% neither agreed nor disagreed, and 12.5% disagreed or strongly disagreed. In the comparison group, 100% of participants agreed with this statement to some extent (strongly agree = 16.7%, agree = 44.4%, slightly agree = 38.9%).

For the statement, "I felt prepared for the in-class session on gait assessment", 18.8% of participants in the intervention group agreed or strongly agreed, 56.3% slightly agreed, 18.8% neither agreed nor disagreed, and 6.3% disagreed. In the comparison group, 27.8% agreed or strongly agreed, 38.9% slightly agreed, 16.7% neither agreed nor disagreed, 11.1% slightly disagreed, and 5.6% disagreed or strongly disagreed.

Most (68.8%) of the participants in the intervention group agreed or strongly agreed with the statement, "The in-class session helped me to apply basic concepts related to gait assessment." Of the remaining participants, 25% slightly agreed and 6.3% neither

agreed nor disagreed. In the comparison group, 61.1% agreed or strongly agreed, 22.2% slightly agreed, and 16.7% neither agreed nor disagreed.

In the intervention group, 68.8% agreed or strongly agreed, 12.5% slightly agreed, and 18.8% neither agreed nor disagreed with the statement, “I enjoyed the in-class session for the gait assessment module.” Of the participants in the comparison group, 66.7% agreed or strongly agreed, 16.7% slightly agreed, and 16.7% neither agreed nor disagreed with this statement.

For the statement, “The learning activities in the in-class session for gait assessment required critical thinking that facilitated my learning”, 56.3% of participants in the intervention group agreed or strongly agreed. Of the remainder, 6.3% slightly agreed, 18.8% neither agreed nor disagreed, and 18.8% disagreed. Of the participants in the comparison group, 44.4% agreed or strongly agreed, 38.9% slightly agreed, and 16.7% neither agreed nor disagreed with this statement (Figure 1).

Many (43.8%) of the participants in the intervention group agreed or strongly agreed with the statement, “The format of the in-class session for gait assessment fit with my learning style.” Of the remaining participants, 37.5% slightly agreed, 12.5% neither agreed nor disagreed, and 6.3% disagreed. In the comparison group, 55.6% agreed or strongly agreed, 22.2% slightly agreed, and 22.2% neither agreed nor disagreed.

In the intervention group, 18.8% agreed or strongly agreed, 43.8% slightly agreed, 25% neither agreed nor disagreed, 6.3% disagreed, and 6.3% strongly disagreed with the statement, “I felt the content in the gait assessment module was more difficult than other topics in this course to-date.” Of the participants in the comparison group, 27.8% agreed or strongly agreed, 27.8% slightly agreed, 11.1% neither agreed nor disagreed, 27.1% disagreed, and 5.6% disagreed or strongly disagreed with this statement (Figure 2).

For the statement, “I feel confident that I can perform a safe and accurate gait assessment”, 43.8% of

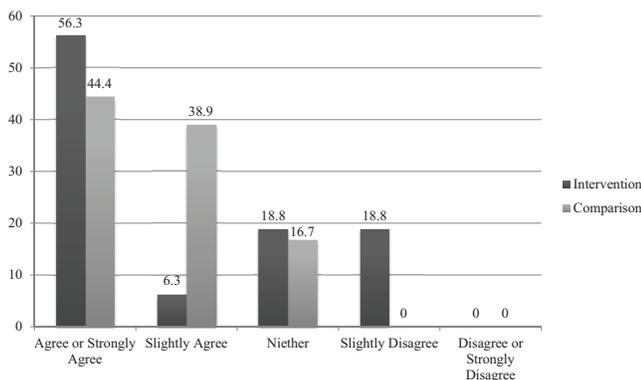


FIGURE 1. The learning activities in the in-class session required critical thinking that facilitated my learning (%).

participants in the intervention group slightly agreed. Of the remainder, 31.1% neither agreed nor disagreed, 6.3% disagreed, and 18.8% strongly disagreed. Of the participants in the comparison group, 5.6% agreed or strongly agreed, 44.4% slightly agreed, 22.2% neither agreed nor disagreed, 16.7% slightly disagreed, and 11.1% disagreed or strongly disagreed with this statement (Figure 3).

When asked what they enjoyed about the gait assessment module, participants in the intervention group wrote they enjoyed the in-class session with the 3D MCS because they could visualize the difficult concepts. One participant wrote, “...it helped me learn way more than I did using the textbook. This is because I’m more of a visual learner, I learn much better if I visually see what we’re learning rather than imagining it as I read what we’re learning in a text book.” Another participant echoed this idea: “The use of the motion capture lab allowed us to see the fine details of movement that would have been missed from observations of the naked eye.”

Participants in the comparison group wrote they enjoyed the in-class session with the traditional gait assessment because it was interactive and allowed them to apply the concepts. One wrote, “i [sic]

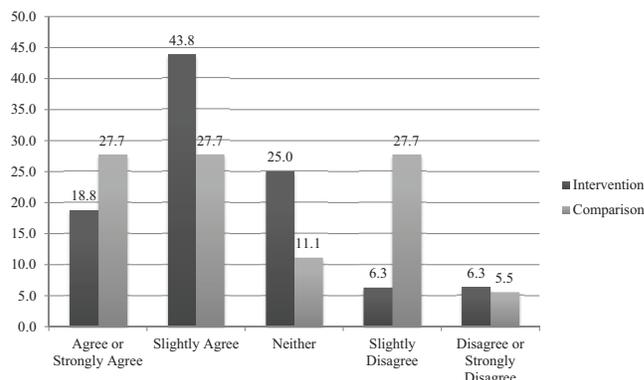


FIGURE 2. I felt the content of the gait assessment module was more difficult than other content to-date (%).

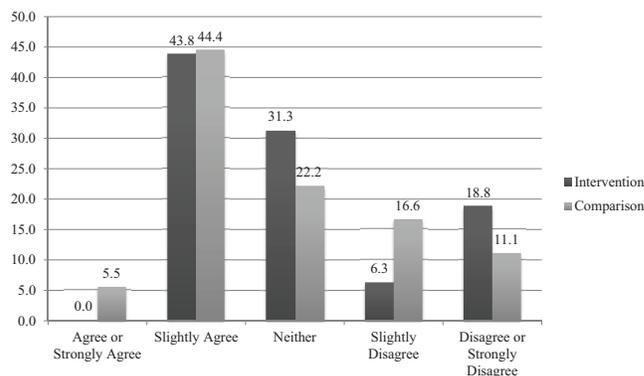


FIGURE 3. I feel confident that I can perform a safe and accurate gait assessment (%).

enjoyed the chance to observe a variety of different gaits when examining the other students in the class. It [sic] gave a variety of body types and showed different real examples of possible pathologies [sic].” Another wrote, “By assessing my classmates, It [sic] helped me to acquire and hone my discerning skills.”

The intervention group recommended adding a more active and hands-on component to the module. This is illustrated by, “I would maybe recommend that we practice assessing gait on other students in class because it would be interesting to see several different gaits and to learn from that.” Some participants mentioned there was a lot of “sitting around and doing nothing”.

Two recommendations from the comparison group were to incorporate an opportunity to create hypotheses about the structures that are causing abnormalities in the gait cycle and to discuss more gait abnormalities. Both groups suggested more time for the GAM, and spoke of needing feedback and to be engaged.

DISCUSSION

Participation was good (94.7%), likely achieved through the integration of data collection and intervention into the curriculum in a way that it did not impact the ‘normal’ student experience. It is likely that students agreed to participate in the study because they were going to do the GAM as a part of the course and the data collection was built into the module. Regardless of their participation, they would have the same experience.

Knowledge of Gait Assessment Theory

Students’ knowledge of gait assessment theory was measured at two points. The results of the pre-online module quiz indicated both groups had little knowledge of gait assessment (intervention = 3.6/10; comparison = 4.0/10 on average). In Humber College’s massage therapy program, most students enter directly from high school, and gait assessment is not typically part of secondary school curriculum. Even those who have transferred from other professional programs (i.e., fitness and health promotion, kinesiology, etc.) have not likely been exposed to the level of detail in this module.

After completion of the online module, students continued to have little knowledge of basic gait assessment theory. The comparison group’s average score only increased by 0.1/10, which was neither educationally nor statistically significant ($p = .83$). The intervention group improved their score by 0.8, but arguably this is also neither educationally nor statistically significantly ($p = .14$). This finding was surprising as we hypothesized the average post-online module score would improve as a result of recent exposure to the material.

This result is actually supported by the literature in education that describes the phenomenon of ‘cramming for a test’ in which students feel more confident that new materials will be remembered in the future. In actuality, despite their confidence, they are unable to recall recently reviewed information.⁽¹⁷⁾ Instead, students (and instructors) should seek out methods of learning that allow for the spacing of knowledge over time.

It is also possible that students completed the pre-online module quiz and post-online module quiz in the same session. In retrospect, this timing of data collection/evaluation did not optimize the students’ abilities to review the material, consider applications, or engage in the content in depth. On the questionnaire, students in both groups reported similar agreement to the statements about the usefulness of the online module and the textbook, indicating both groups likely had similar experiences with, and perhaps similar approaches to, the online module. Considering these factors, the finding of no change in either group is reasonable.

Application of Gait Assessment Theory

The main hypothesis was that the introduction of the 3D MCS would increase the ability of students in the intervention group to apply the theory of gait assessment. Although the difference between the groups was not statistically significant ($p = .13$), the intervention group did have an average score that would be considered a passing grade. While the assessments were not similar enough in their structure and content to compare statistically, it is interesting to note the change. The intervention group began with 3.6/10, then progressed to 4.4/10, and finished with a score of 5.4/10. The comparison group began with 4.0/10, then progressed to 4.1/10, and finished with an average score of 4.1/10. It does seem, from these scores, the intervention group was slightly better than the comparison group when applying the theory to a video of a person walking.

If the intervention truly had no effect on the ability of students to apply the theory to practice, and it is not a small effect undetectable by the small sample (discussed below in limitations), then it is possible that the student-identified ‘lack of engagement’ may have impacted the success of the intervention. Most students in both groups agreed that the in-class session helped them and they enjoyed it. When asked about what they would change, the intervention group suggested adding the traditional approach to enhance the technology. Conversely, the comparison group did NOT suggest adding the technology to their experience.

One possible explanation is that the comparison group enjoyed the interactivity of their in-class session. Most agreed that it made them think critically. The intervention group enjoyed the visual

representation of gait, but 18.8% slightly disagreed and 18.8% neither agreed nor disagreed that the in-class session made them think critically. Students were not given a definition of ‘thinking critically’; therefore, we cannot be certain what that meant to them.

Some of the intervention group described the in-class session as “a lot of sitting around and doing nothing”. There are at least three factors that may create this experience. First, only one person at a time can be assessed using the 3D MCS. Second, only a few people landmark the volunteer using the reflective markers. Third, the processing of the data can take approximately 5 to 10 minutes. Together, these factors resulted in most of the students having to wait for periods of time, which may have impacted their experience. It is interesting to note that none of the students in the comparison group took advantage of the opportunity to use the 3D MCS after the study concluded.

Confidence to Perform Gait Assessment

Overall, both groups reported low confidence in their ability to perform gait assessment. This finding seems reasonable given the other factors discussed above. Students needed more time to gain confidence. This fits with the idea previously mentioned about needing to time introduction, practice, and evaluation of concepts so students can retain and use the information in the future.⁽¹⁷⁾ Also, this is congruent with the program’s expectations of the students. In Semester 2, students are exposed to the theory and basic application of gait assessment. In later semesters, this foundation is reinforced and built upon to include abnormal gait.

In the future, students may feel more prepared with a combination of the traditional GAM and the 3D MCS. Therefore, we propose the following adjustments.

1. Introductory online module. The learning objectives, reading, and videos would be kept as the first introduction to the terms and concepts.
2. In-class session. This would begin with a large class discussion about concepts of gait assessment and would answer questions from students. Then, the large group would conduct a gait assessment of one student. In small groups, students would apply the theory by observing one group member. After recording their findings, they would test that student’s gait using the 3D MCS. Groups would cycle through the 3D motion capture lab. As one group finished and waited for their results, the next group would be applying the reflective markers. Once students received their results from the 3D MCS, they would compare the results with their previous observations.
3. Evaluation. The pre- and post-online module quizzes would be kept and a third knowledge quiz added after the in-class session. This could

easily be combined with the application quiz/questionnaire. Formative feedback would be added wherein the comparison of findings would be discussed with the instructor, allowing students to gain understanding of whether they were appropriately applying the theory.

Limitations

One of the limitations is that the third assessment, administered following the in-class session, did not measure knowledge in the same way as the first two. This limited our ability to measure whether the experience of the in-class session, and introduction of additional time to review the theory associated with gait assessment, improved knowledge acquisition. Future studies should consider this addition.

Another limitation is the small sample size. It is possible the intervention had no real effect (as evidenced by the lack of statistical significance between groups, especially in the application quiz). It is also possible there was some effect, too small to capture with our sample. Future studies should make an effort to increase the sample size, keeping in mind it is difficult to do in educational research, as one cannot simply enroll more students into a given class.

CONCLUSION

Massage therapy students learn gait assessment as a part of physical assessment. Traditionally, the GAS has been low-tech. The benefit of this method, discovered through this study, lies in the interactivity, and subsequent engagement, of students. The integration of technology, in the form of the Qualisys 3D MCS, was novel and provided students the opportunity to visualize the theory they were learning. However, students reported that they were not engaged during the experience. In the future, we recommend combining the traditional module with technology to optimize the benefits of each. The Qualisys 3D motion capture system can cost hundreds of thousands of dollars. This combination of technology is recommended for programs that can arrange access to existing technology. It is not recommended that massage therapy programs invest in this technology, unless they can share the cost with other programs in their institution.

Furthermore, more time is needed for students to gain confidence with gait assessment. The results of the knowledge and application assessments did not show any significant change or difference between groups. Addressing the limitations of this study by adjusting the third assessment to be comparable to the other two and increasing the sample size may impact the ability to show changes in knowledge and application in the future.

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CONFLICT OF INTEREST NOTIFICATION

The authors declare there are no conflicts of interest.

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