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Original Research

Investigating the Effects of Visual Feedback on Muscle Activity, Heart Rate, RPE, and Perceptions of Performance in Ballet Dancers

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ABSTRACT

International Journal of Exercise Science 17(1): 1056-1067, 2024. Extreme postures and imbalances in neuromuscular activity may place classical ballet dancers at higher risk of injury. Dance studio mirrors provide visual feedback by which a dancer can self-correct their body position and alignment, but have been suggested to negatively impact kinesthetic abilities and decrease performance capabilities. Thus, we investigated the effects of a mirror on muscle activity of the quadriceps, heart rate (HR), rating of perceived exertion (RPE), and qualitative performance. A lack of visual feedback would increase muscle activity of the quadriceps, HR, and RPE, and decrease self-reported perception of technical quality. 10 female participants completed a single leg balance, an adagio, and a jump task twice – once in each condition. Muscle activity of the vastus lateralis (VL) and vastus medialis oblique (VMO), as well as HR and RPE were assessed during each combination. Qualitative performance was assessed with an exit survey. No significant differences were found between conditions for RPE or HR in all three tasks (RPE: Balance p = 0.468, Adagio p = 0.191, Jumps p = 0.769; HR: Balance p = 0.409, Adagio p = 0.424, Jumps p = 0.244). No significant differences were found between conditions/tasks for peak, mean, and RMS sEMG. Dancers significantly ranked their artistic expression lower in a non-mirror condition (p = 0.018, Cohen's d = 0.775). No differences in muscle activity of the VMO and VL or vital signs of fatigue were found. Psychological implications of visual feedback, including dancer's perceived decrease in artistic expression without a mirror present, should be further explored in future studies.

KEY WORDS: Kinesthetic feedback, surface electromyography, dance pedagogy, somatic dance, indicators of fatigue

INTRODUCTION

Within the Renaissance period, ballet dance was centered around expressive movement to tell stories, and typically was an accompaniment to operas and live performances in the courts of nobles (2). However, the invention of the pointe shoe and the creation of full-length story ballets led to the demand for ballet technique, such as body flexibility and leg extension, complex leaps and turns, and fast footwork (2). The focus on ballet training shifted to include intense physical training to perform movements that would impress the audience with how difficult they were to complete (2). In a typical dance studio, a mirror is located at the front of the room, and spans an entire wall. Its purpose is to replace a live audience and be a source of visual feedback for training dancers, as it allows them to fully see their body, self-adjust, and make corrections to their alignment and position based on what they see (8, 9, 25, 27).

Classical ballet dancers, like most athletes, engage in rigorous training with high physical demands on the body (1, 6, 14, 21, 28, 30, 33). However, because of the extreme positions created by the body in dance, dancers are placed at higher risk of injury (6, 30, 33). The discipline of ballet, in particular, requires a high level of specified body placement, hereon referred to as technique. Technique emphasizes maintaining maximal external hip rotation through all classical ballet movements. When this maximal position of the hip isn't utilized properly, there is a high chance of dancers adopting muscle compensatory strategies, such as ankle overpronation, increased lumbar lordosis, or tibial rotation (6, 14, 21, 27, 30, 33). Furthermore, imbalances in neuromuscular activity during repetitive training of these movements have been shown to contribute to the development of overuse injuries (1, 6, 30, 33).

Dancers may rely on visual, auditory, sensory, and kinesthetic feedback to assess their movement performance. Auditory feedback includes paying attention to the music and how the movement is expressed with the time signature. Verbal feedback from instructors is also important, and may be comprised of postural or artistic corrections from the instructor (10, 19, 24, 25, 27). Sensory feedback is a part of the proprioceptive system, which (along with auditory feedback), aids in balance and coordination (22). Kinesthetic feedback is an instantaneous intrinsic feedback system provided by the stretch receptors of the muscles, tendons, and joints and may play a role in modulating motor output, which can be assessed with surface electromyography (sEMG) (3, 5, 8, 10, 19, 25, 27, 28).

Humans have a limited capacity to receive, process, and respond to feedback, and therefore, may rely on one feedback system more than another to improve the quality and technique of their dancing (3, 5, 8, 10, 19, 27). Most commonly, the source/system utilized is visual feedback via the use of a mirror due to its accessibility and ease (8, 10, 25, 27). However, utilizing the mirror as a primary source of feedback in dance may impair rather than enhance performance. When using a mirror, the dancer's perception of self is only seen from one direction, creating a perceived distorted image. Subsequently, a dancer may unintentionally impair the position or placement of the body when utilizing a mirror by prioritizing visual feedback over kinesthetic awareness (5, 8, 27, 19). Further, Radell and colleagues report that dance performance and skill acquisition may decrease with the use of a mirror in dance training (26). The use of a mirror in dance training has also been reported to negatively affect perceptions of body image, increase self-criticism, and decrease dancers' ability to perform and train without a source of visual feedback (8, 10, 24, 25, 27).

There is limited research on the effects of the use of visual feedback specifically in ballet dancers, as well as the effects of ballet dancing with or without a mirror on HR and RPE (25, 30). Studies examining effects of a mirror on movement performance and skill acquisition have been explored in relation to Pilates training, running, and weightlifting, and have demonstrated mixed results. This suggests the complexity of the use of the mirror on motor control and athletic training throughout a variety of athletic disciplines (11, 18, 29). A further understanding of the relationship between the use of a mirror and its effects on physiological variables in dance has yet to be explored.

The purpose of this study was to investigate the effects of visual feedback via a mirror, on muscle activity of the quadriceps muscle, heart rate (HR), rate of perceived exertion (RPE), and perceptions of performance, in collegiate intermediate/advanced-level ballet dancers. It was hypothesized that an acute lack of visual feedback would increase muscle activity of the quadriceps muscle, HR, and RPE, and decrease self-reported perception of technical quality and body placement**.**

METHODS

Participants

Participants were recruited from the dance department at Skidmore College. Participants were 19.9 ± 1.87 years old, with 12.4 ± 2.9 years of self-reported ballet training experience. One participant's sEMG data for the adagio task was unable to be analyzed due to a computer/human error. Upon indicating their interest in participation, candidates were emailed an Intake Survey, which assessed eligibility. Inclusion criteria mandated that all participants to be over 18 years old, and currently enrolled in an intermediate-advanced ballet class. In addition, participants must have had at least three years of ballet training, and no active illness or injury preventing their ability to dance. Injury and illness status were self-reported. Students with no prior ballet experience, or an active injury/illness were excluded from participation. Participants provided written informed consent prior to participating, and were familiarized with the equipment being utilized in the study prior to testing. This study was reviewed and approved by the Institutional Review Board at Skidmore College (IRB# 2302-1074). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (20).

Protocol

Using a randomized paired design, participants were assigned an ID number, and divided into two groups using a number randomization generator, to distribute condition order (Figure 1). Group 1 engaged in testing with a mirror image (MI) present first and no-mirror (NM) present for the second trial, while Group 2 engaged in testing with NM for the first trial and utilized an MI for the second. All trials occurred in the Dance Department studios at Skidmore College, which contain mirrors with curtains that were raised or lowered between conditions.

Prior to testing, each participant engaged in a structured warm-up activity which included pliés (maximal external hip rotation with slow, sustained knee flexion), tendus (hip flexion, abduction, and extension, with plantarflexion), and cloches (leg swings consisting of hip flexion and extension), along with brief upper body stretching. After the warm-up, each participant completed their first test in their first assigned condition (MI or NM). The participants were shown a standard sequence of ballet movements (hereon referred to as a movement phrase), and then asked to demonstrate it. The phrases were: a single leg balance on demi-pointe (heel raised) until failure, a slow-motion phrase or 'adagio' consisting of balancing and leg extension tasks (approximately 40 seconds of sEMG data collection), and a jump task of 32 'sautés' with hips in external rotation or 'first position' (approximately 25 seconds of sEMG data collection). Participants in both groups completed the movement phrases in the same order as stated above. After the first assigned condition was completed, participants were given a five-minute rest, then completed the same three-phrase test in the second assigned condition by either raising or lowering the curtains for the mirrors (Figure 1).

Each enrolled participant was asked about which leg they would prefer to kick a ball with to determine the dominant leg, from which data would be collected. The dominant leg was the standing leg for the balance task, and the working leg for the adagio task. HR was collected using a chest strap style heart rate monitor and the corresponding Polar Beat app (H7, Polar USA, Lake Success, NY, USA). Prior to the testing, participants were instructed on the placement of the Polar H7, which was dampened before being strapped around the chest, underneath the breastbone. Borg Scale was utilized to measure RPE throughout the testing procedures, as it has been shown to be a valid assessment of training load in dancers (31). Borg RPE was verbally asked and reported during the midpoint of each exercise, with the exception of the single-leg balance, which was asked every 10 seconds until failure, and then upon conclusion of the balance (35).

Muscle activity of the quadriceps was measured using surface electromyography (sEMG) utilizing the Delsys Trigno Avanti Wireless Biofeedback System (Delsys Inc., Natick, MA), with sensor model SP-W06 and base station model SP-W02 (9). Surface sEMG utilizes a receiver, electrodes, and specialized software to gather information about characteristics of muscle contractions, such as intensity and duration, during a wide variety of sports and movements (4, 12, 15, 16, 32). The Trigno Avanti System utilizes a Signal Amplification and Analog Band Pass Filter at the senor (20-450hz), in addition to a built-in Butterworth bandpass (40/80 dB/dec, forward and reverse) applied to the source data. The acquisition rate of data collection for this study was 1259hz. EMGWorks Acquisition software was used to record muscle activity data, and EMGWorks Analysis software was used for data analysis and any necessary data processing and calculations (17, 23). Prior to analysis, extraneous baseline noise in the data was automatically removed with a low pass filter. The data was then processed using full-wave rectification. sEMG data was further processed in the time domain. A root mean square (RMS) calculation script was utilized to rectify the data and remove the mean offset to balance varying baseline voltage levels from the individual sensors. Along with the RMS, Mean Absolute Value (MAV) was obtained, and compared between MI and NM conditions (9).

Participants were asked to wear comfortable clothing that would not impact placement of the sEMG sensors, such as athletic shorts. Participants were then fitted with two sEMG surface electrodes, placed onto muscles of the quadriceps, specifically the vastus medialis oblique (VMO) and vastus lateralis (VL) of the dominant leg. In order to reduce potential signal transmission error, the skin site was shaved and abraded with an alcohol wipe. Each sensor was placed on the muscle belly parallel to the muscle fiber direction, and secured to the leg with surgical tape. The VL sensor was placed 4cm lateral and 5cm superior to the patella, while the VMO sensor was placed 4cm medial and 5cm superior to the patella.

To assess perceived qualitative performance, each participant was emailed a digital Exit Survey to reflect performance quality, as well as the perception of the dancers' fatigue levels in each condition. Participants were asked to reflect on and rank their perceptions of balance, coordination, exertion, and artistic expression, separately, for each condition. A Likert scale from 1–4 was utilized to explore each category, where 1 = significantly weaker while 4 = significantly stronger. A second Likert scale ranging 1–10 was utilized to explore any negative feelings during the trials. Participants were asked to rank feelings of anxiety, lack of confidence, frustration, self-criticism, and being overwhelmed, where 1 = did not experience this emotion, and 10 = experienced this emotion to a large degree. Open-answer questions prompted the participants to reflect on any potential feelings of anxiety or stress, when asked to complete the trial without the mirror, or feelings of relief while dancing with the mirror uncovered (regardless of group). Participants were then given the opportunity to express any other experiences from their trial.

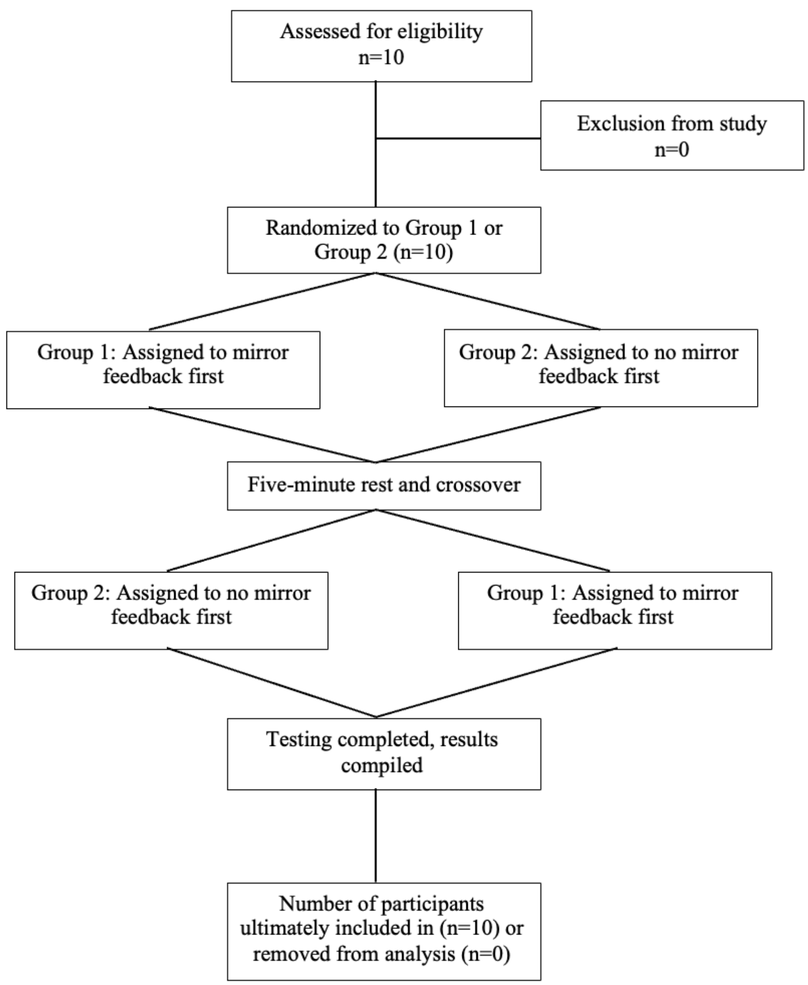

Figure 1. Experimental design flowchart.

Statistical Analysis
All statistical analyses were completed using open-source software, primarily JASP (v 0.16.3, Amsterdam, Netherlands), Microsoft Excel (v 16.65, Redmond, Washington), EMGWorks Acquisition and Analysis (v 4.7.3.0, Natick, Massachusetts). As little to no prior literature has been conducted on this subject, data from prior works was not utilized to inform the power analysis. A power analysis conducted with G*POWER 3.1.9.6 (Universitat Kiel, Germany) determined that 27 participants were needed in the study for a power of 0.8, an effect size of 0.5, and an alpha = 0.05. JASP was utilized to conduct a Shapiro-Wilk test of normality, to explore normal distribution, and affirm no alternative procedures were needed. The data did not violate the assumption of normality; therefore, no additional procedures were necessary. Given the directional hypotheses, one-tailed paired *t*-tests were conducted to analyze the data. Cohen's *d* was used to estimate effect size, with values of 0.2, 0.5, and 0.8 indicating small, medium, and large effects, respectively. The level of significance was set at $p < 0.05$. All data are expressed as means ± standard deviation, unless noted otherwise.

RESULTS

No significant differences were found between conditions for peak sEMG, mean sEMG, or RMS in either the VL or VMO muscles during each of the three ballet tasks (Peak: Figure 2; Mean: Figure 3). More specifically, no difference was found in peak sEMG for the balance, adagio, or jumps between conditions for VL (Figure 2) or VMO (Figure 2). Similarly, no significant differences were found in mean sEMG throughout each of the conditions and tasks for the VL (Figure 3) and VMO (Figure 3). Finally, no significant differences were found in RMS between the two conditions for each task for the VL or VMO. No significant differences were found in reported RPE between the MI condition and NM condition for all three combination tasks (Figure 4). While HR data trended towards being higher within the NM condition, no significant differences were found between conditions for average HR among the three combination tasks (Figure 5).

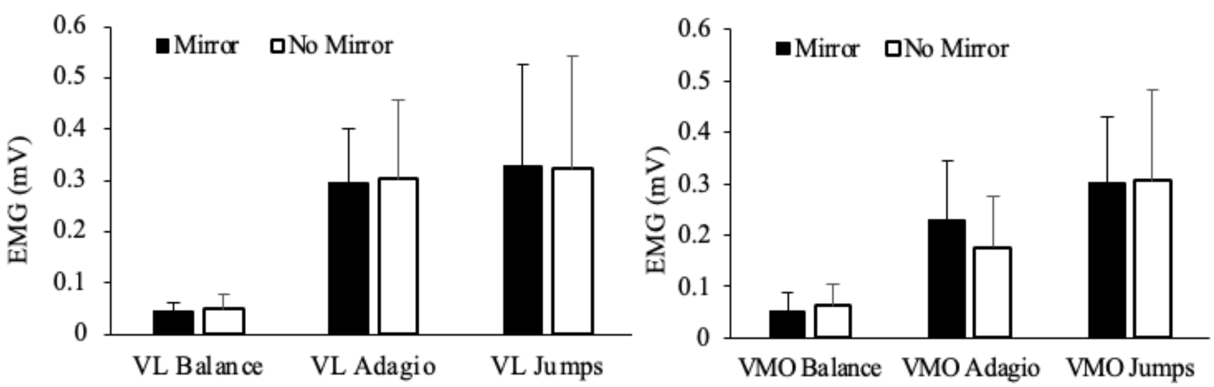

Figure 2. Average peak sEMG for vastus lateralis and vastus medialis oblique muscles while completing three dance tasks with and without a mirror. Data are mean + standard deviation. Balance and Jumps $n = 10$, Adagio $n = 9$. Vastus Lateralis: Balance: $p = 0.244$, $d = 0.228$; Adagio: $p = 0.448$, $d = 0.045$; Jumps: $p = 0.636$, $d = 0.114$. Vastus Medialis: Balance: $p = 0.109$, $d = 0.418$; Adagio: $p = 0.981$, $d = 0.981$; Jumps: $p = 0.478$, $d = 0.478$)

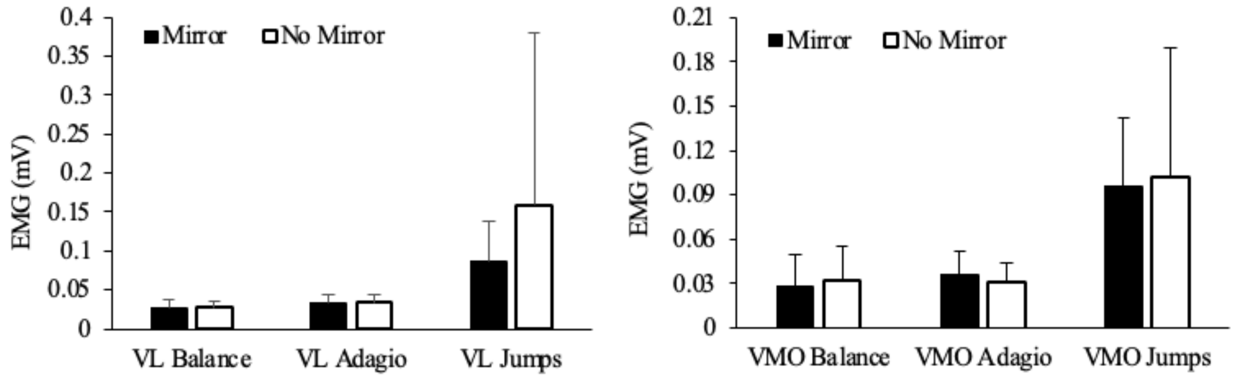

Figure 3. Mean Absolute Value (MAV) sEMG for vastus lateralis and vastus medialis oblique muscles while completing three dance tasks with and without a mirror. Data are mean + standard deviation. Balance and Jumps n = 10, Adagio n = 9. Vastus Lateralis: Balance: p = 0.488, d = 0.009; Adagio: p = 0.515, d = 0.013; Jumps: p = 0.165, d = 0.326. Vastus medialis: Balance: p = 0.100, d = 0.438; Adagio: p = 0.902, d = 0.471; Jumps: p = 0.395, d = 0.087).

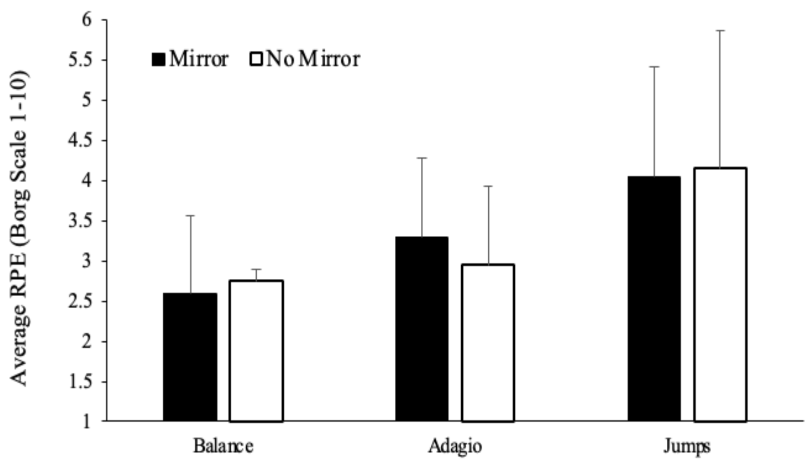

Figure 4. Comparison of Rating of Perceived Exertion (RPE) across three ballet tasks in each condition (n=10). Data are mean + standard deviation. (Balance p = 0.234, d = 0.340, Adagio p = 0.904, d = 0.047, Jumps p = 0.385, d = 0.095).

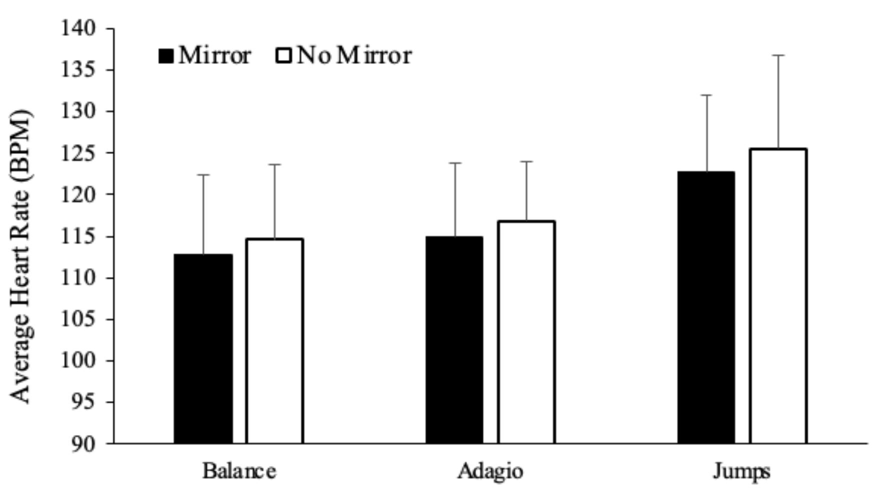

Figure 5. Comparison of average Heart Rate HR across three ballet tasks in each condition (n = 10). Data are mean + standard deviation (Balance p = 0.409, d = 0.274, Adagio p = 0.424, d = 0.265, Jumps p = 0.244, d = 0.394).

In the qualitative exit survey, participants were asked if they felt anxious or unsettled when they were asked to complete the series of combinations without the mirror (Figure 6). 60% of the participants reported feeling anxious or stressed, although not to a large degree. 30% of the participants said they did not feel anxious, due to having routine classes or rehearsals without the mirror. 50% of the participants reported feeling "unnatural" dancing without a mirror because they had to readjust to focus more on their kinesthetic sensations, which was strange only at first. 60% reported the balance task being easier with the mirror, and 70% reported feeling either self-conscious or critical of their placement and body image. Aside from the qualitative comments, participants ranked their balance, coordination, and artistic expression lower on average during the NM condition than the MI condition, but only artistic expression was significantly ranked lower during the NM condition, with a moderate–large effect size (Balance: $p = 0.278$, $d = 0.194$. Coordination: $p = 0.254$, $d = 0.218$. Exertion: $p = 0.500$, $d = 0.000$. Artistic expression: $p = 0.018$, $d = 0.775$).

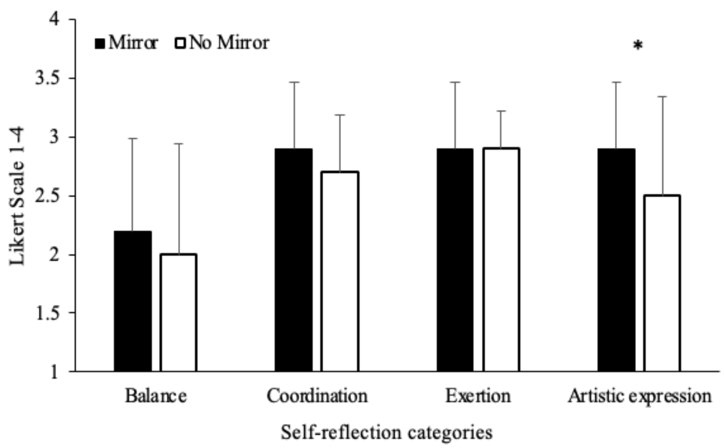

Figure 6. Self-reported perceptions of balance, coordination, exertion, and artistic expression during each condition (1 = Significantly worse, 4 = significantly better) in ballet dancers ($n = 10$). Data are mean + standard deviation. (Balance: $p = 0.278$, $d = 0.194$. Coordination: $p = 0.254$, $d = 0.218$. Exertion: $p = 0.500$, $d = 0.000$. Artistic expression: $p = 0.018$, $d = 0.775$) $^*p < 0.05$ between conditions.

DISCUSSION

The purpose of this study was to investigate the effects of visual feedback via a mirror, on muscle activity of the VMO and VL, HR, RPE, and perceptions of performance, in collegiate-aged, int/adv-level ballet dancers. It was hypothesized that an acute lack of visual feedback would increase muscle activity of the quadriceps, HR, and RPE, and decrease self-reported perception of technical quality and body placement. Results for RPE did not support the hypothesis, suggesting that the dancers did not experience higher rates of exertion when visual feedback was restricted. The verbal reporting of RPE and the survey data are indications that a lack of visual feedback does not have an effect on exertion or fatigue. While the results for HR trended towards supporting the hypothesis, the data was not significant, and therefore no definitive conclusion could be made. Of note, there is a lack of research on the impact of visual feedback on HR in dance. Higher HR could stem from increased levels of anxiety simply as an autonomic response to an environmental stressor, rather than exertion, which would be consistent with the qualitative feedback received from the participants.

Chatfield (5) and Wilson (36) suggest the inherent variability in sEMG muscle activation patterns in dancers. Due to the complex movement patterns and joint position in dance, each attempt of a dance movement during performance will be different. More advanced dancers will demonstrate decreased variability in muscle activation while dancers with lower levels of technique will demonstrate increased variability. The degree of muscle activation variability within a movement can be used to determine how dancers of different skill levels are able to control their muscles and adapt to changing events and conditions. In the present study, there were no significant differences in sEMG muscle activity of the VMO and VL between the two conditions, which did not support the hypothesis. However, this lack of significance indicates a consistency within the dancers' technique in both the MI and NM conditions which may be attributed to their level of training and overall ballet technique proficiency (5).

While some dance disciplines spend time learning and dancing without a mirror (EX: modern or contemporary dance), the discipline of ballet traditionally relies heavily on the use of a mirror for visual feedback during training (25). Of note, the use of training in a NM condition is a pedagogical strategy known to be utilized as a part of the curriculum within the department where this research was conducted. As a result, participants were regularly immersed in this style of learning environment. However, this training methodology is not standard at other institutions of higher education and/or ballet schools across the world. Therefore, the results of this study may differ if participants were exclusively enrolled in either exclusively modern or ballet courses, or if they were recruited from an institution with different curricular training regimens.

In the exit survey, participants ranked their balance and coordination lower on average during the non-mirror condition, and ranked their artistic expression significantly lower when visual feedback was restricted. While this supported the hypothesis, the self-reports from the exit survey pose an interesting contradiction. The participants reported discomfort when they were asked to dance without the mirror, and explained feeling that their artistic capabilities were limited. However, they additionally reported feeling higher levels of self-criticism when asked to perform with the mirror. Radell theorizes that the mirror can become a "crutch" for the dancers, which may inhibit them from developing their kinesthetic abilities, and therefore inhibiting them from improving their performance capabilities (25). The results of the exit survey in regards to performance and artistic expression align with this concept of inhibiting performance capabilities when access to visual feedback is restricted. It appears that training within both conditions is necessary to improve placement and performance capabilities. These data suggest the complexities of the use of a mirror in dance and center the importance of utilizing both MI and NM conditions as standard practice in ballet training and education.

While requiring the participants to have a specified amount of training and be currently enrolled in a ballet course worked to eliminate potential biases and ensure participant safety, the inclusion criteria limited the pool of potential participants, resulting in a small sample size that could have had an effect on the statistical analysis results. As previously stated, many students were dual enrolled in ballet and modern dance classes, which may have increased potential bias within the results. In the present study, each dancer completed one trial of the same tasks in each condition. Furthermore, each dancer only completed the trial using their dominant leg. It is recommended that future research engage dancers in multiple trials to account for the known variability of sEMG activation patterns in dancers. An exploratory or confirmatory factor analysis (EFA/CFA) was not utilized to validate the exit survey questions, and therefore may not be a valid measure of assessment for the self-perceived balance, coordination, exertion, and artistic expression. Thorough research did not show an existing survey to obtain this information, thus an EFA/CFA is needed to validate the exit survey and the findings in this study.

No significant differences in muscle activity of the VMO and VL, or changes in RPE, or HR were found between MI and NM conditions. Participants perceived a decrease in their balance and coordination on average during the non-mirror condition and perceived their artistic expression significantly lower when visual feedback was restricted. While these data could be an initial indication of the complexities of the use of a mirror in ballet training, a larger sample size is recommended to fully validate these findings. Future research may also benefit from studies involving dancers of different skill levels, including novice dancers, and the use of a mirror for skill acquisition in this population. Further exploration into the dancer perceptions and subsequent psychological effects of the mirror on dance training is also recommended.

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All authors declare that they have no conflicts of interest.

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