March 2022

The Effects of Video Feedback on Running Form

Mariana Morante
University of South Florida

The Effects of Video Feedback on Running Form

by

Mariana Morante

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Applied Behavior Analysis
Department of Child and Family Services
College of Behavioral and Community Sciences
University of South Florida

Co-Major Professor: Raymond G. Miltenberger, PhD., BCBA-D
Co-Major Professor: Kimberly Crosland, PhD., BCBA-D
Bryon Miller, PhD., BCBA-D

Date of Approval:
March 1, 2022

Keywords: performance, athletic skill improvement, injury prevention, jogging

Dedication

I dedicate this manuscript to my parents, Karen Bjorge and Jean Pierre Morante, as well as my boyfriend, Juan Alviz. Thank you for supporting everything I am passionate about and that has shaped me to be who I am today. Thank you for believing in me when I did not believe in myself.

Acknowledgements

I would like to acknowledge my thesis committee and the professors at the USF program who have taught me a lot about behavior analysis and have allowed me to expand my horizons. I also would like to acknowledge my advisor Dr. Miltenberger for allowing me to bridge together sports and behavior analysis, the two things I am very passionate about.

I am grateful for my research assistant Tiera Palmisano, who has taken countless hours out of her day to assist me with data collection and scoring videos, while also helping me maintain paperwork organized.

Finally, I would like to thank Cristina Nunez for taking me under her wing and molding me into the behavior analyst I am today. Thank you for giving me the opportunity to work for you, allowing me to gain experience, and for guiding me to become a strong and competent behavior analyst.

Table of Contents

List of Figures

Abstract

Individuals should use proper form while running to prevent injuries. Running with rear-foot strikes (RFS) are associated with greater injury (e.g., Arendse et al., 2004; Daoud et al, 2012), while front-foot strikes (FFS) and mid-foot strikes (MFS) are found to produce less impact on a runner's leg. Video feedback has improved athletic skill performance in a number of sports, which frequently targets athletic form (BenitezSantiago & Miltenberger, 2016; Kelley & Miltenberger, 2016; Schenk & Miltenberger, 2019). Proper running form is important for injury prevention and can promote continued engagement in running as a long-term form of exercise. A behavior analytic account of video feedback has been shown to be effective with a number of sports, but it has not been evaluated for improving running form. The purpose of this study will is to evaluate the effectiveness of video feedback to improve running form in experienced runners. During baseline, each participant was video recorded while running at a jogging pace, and no feedback was given. For the video feedback intervention, the researcher recorded the participant, then showed each participant the video and provided feedback on correct or incorrect form, according to the 9-step task analysis. Video feedback was shown to be effective on improving running form. All three participants achieved criterion during the feedback session, and it maintained during the follow-up phase.

Chapter One: Introduction

Running is a popular form of exercise practiced by many people worldwide (Lange, 2020). According to Lange (2020), survey results indicated about 60 million individuals engaged in running, jogging and trail running in 2017 in the United States alone. He also reported that improving physical health was a main motivator for Americans to start running. There are many health benefits that come from engaging in running on a regular basis. Running allows that sufficient flow of blood and oxygen travels the body, which decreases risk of heart attacks (Cantwell, 1985). Aerobic exercise helps combat diseases that affect cognitive ability like Alzheimer's disease (Guiney & Machado, 2013). Engaging in 30 min of running each day during the week for about three weeks helps improve sleep, mood, and concertation (Guiney & Machado, 2013). Boecker et al. (2008) suggested that running combats stress because a "runner's high" is experienced when endorphins produced by running release and boost mood. Boecker et al. also described running as an activity that is associated with reward because runners may have euphoric experiences like finishing a run faster or achieving a personal best.

In a 2007 review of the literature on running injury of the lower extremities by van Gent et al., the overall incidence of injury was found to range from 26% to 92%. Re-occurrence of injuries have been reported to occur in the range of 20% to 70%, and runners reduce or cease their running activities for 30% to 90% of all injuries (van Mechelen, 1992). Although some research suggests that running with rear-foot strikes (RFS) are associated with greater injury (e.g., Arendse et al., 2004; Daoud et al, 2012), especially an increase knee-impact injuries, front-foot strikes (FFS) and mid-foot strikes (MFS) can result in ankle-impact injuries, such as those related to the tibia, Achilles tendon, and arch (Goss & Gross, 2013; Kumar, 2015; Michaud, 2016). Moreover, runners who run with MFS and FFS tend to use shorter stride length or stride reach, and increased step rate, or cadence (Heiderscheit et al., 2011; Kumar et al., 2015). Michaud (2016) has suggested that injury may have more to do with runners decreasing stride and increasing cadence than the specific foot strike used. Nonetheless, because techniques involving MFS and FFS are associated with shorter strides and low cadence, these may be desirable strike patterns to promote for running technique when knee-impact injuries are a concern. Considering the majority runners typically use a RFS pattern (Daoud et al., 2012; Kleindienst et al., 2007), it is not surprising that a predominate site of injury is the knee, ranging from 7.2% to 50% of injuries (van Gent et al., 2007). However, if runners are concerned with ankle-impact injuries, then they should be taught to use a RFS pattern to lessen the initial impact on the ankle and arch area (e.g., Goss & Gross, 2013; Kumar, 2015; Michaud, 2016).

Various feedback interventions have been utilized in the kinesiology literature such as verbal cueing (e.g., Diebal, 2011 & 2012; Messier & Cirillo, 1989), auditory cueing (e.g., Diebal, 2011; 2012), biofeedback (e.g., Davis & Futrel, 2017), mirror training (e.g., Agresta & Brown, 2015; Miller et al., 2020; Michaud, 2016), and real-time visual feedback (e.g., Clansey et al., 2014; Crowell et al., 2010), and video feedback (Diebal, 2011; 2012; Messier & Cirillo, 1989; Miller et al., 2020).

Messier and Cirillo (1989) used statistical analysis to evaluate the effects of video modeling, verbal feedback, and live video feedback on running form. They compared the pre- and post-test values of perceived exertion and running economy across a test and control group. Each group consisted of 11 women who had no prior running experience. Both groups ran on a treadmill three times a week for 5 weeks, with each run lasting 20 min. For the run training (test) group, sessions began with showing the participants a video of an expert runner and a video of their own running pre-test. Each participant's running form was recorded for the first and last 7 min of the treadmill run. A monitor was placed in the participant's view for live video feedback of their own running. The researcher also gave the participants verbal feedback about the biomechanical goals at the one- and ten-minute mark. Although no significant differences were found for perceived exertion or running economy, results indicated a significant difference for the experimental group compared to the control group for improvements to some aspects of running form. The main improvements included desired changes in the knee and ankle angles, foot strike patterns, and stride length.

In a case series study, Diebal et al. (2011), used a pre- and post-test comparison to evaluate teaching FFS running to improve step length, step rate, ground force (impact), and impulse (contact time) for two participants with chronic exertional compartment syndrome (CECS). The authors reasoned that FFS training was a potential nonoperative option to decrease running pain associated with CECS, a condition associated with running that is typically treated by surgical means. Each session was 1 hr and occurred three times a week for 6 weeks. The intervention components included drills and exercises (weight shifting, falling forward, foot tapping, high hopping, and running with a specialized belt), barefoot running with verbal cues to "run quietly," and video feedback by showing a video recording of their run on a laptop. Although the authors reported more intensive video feedback was required for one of the participants, no information was provided about how or when video feedback was implemented (before, during, or after the run) in either case. Improvements were indicated for all four post-test measures for both participants; however, these results are significantly limited because this study did not utilize any experimental control. Nonetheless, after 6 weeks, both participants reported running regularly without pain in the absence of any surgical intervention.

In a 2012 follow up study, Diebal et al. similarly evaluated FFS training to reduce pain during running for participants with CECS. They used statistical analyses in a pre- and post-intervention for 10 participants. The intervention was identical to Diebal et al. (2011), except that it also included auditory cueing with a metronome. Statistically significant improvements were found in post-intervention assessments for all 10 participants, including decreases in post-running compartment pressure in the lower leg, decreases in stride length, and increases in step rate; however, changes in foot strike patterns were not directly measured or analyzed. Similar to Diebal et al. (2011), pain was substantially reduced, and training FFS form precluded any surgical intervention all 10 participants.

More recently, Miller et al. (2020) used nonparametric statistical analyses in a pre- and post-intervention group design to evaluate a gait retaining program to teach nine runners to change their RFS pattern to a FFS pattern. Gait retraining consisted of a treatment package involving instructions, audio cueing (metronome), verbal feedback, and video feedback. All nine participants successfully transitioned from RFS to FFS or MFS patterns.

Each of the above studies included a video feedback component; however, this was not the sole intervention for any of them, thus any conclusions about the effects of video feedback on running form cannot be determined from these results. More importantly, the way in which video feedback was used (type of feedback, number of viewings, etc.) was not clear, and with the exception of Messier and Cirillo (1989), when video feedback was provided was also ambiguous. For example, Miller et al. (2020) described video feedback only as a post-run feedback for the participants. That is, it was not clear if the participants were given any opportunity to correct their form immediately following the video feedback. Furthermore, the brief and varied descriptions for all four studies suggest a high likelihood that the implementation of video feedback was inconsistent across studies. Last, three of the studies employed statistical analysis for groups with a small N-value, and one study consisted of two non-experimental case studies (Diebal et al., 2011). Given that athletes, especially runners, are trained on an individual basis and that outcomes may be idiosyncratic, a single-subject experimental design may better suit an analysis of the effectiveness for interventions designed to teach or shape running form (Barker et al., 2011).

There is an abundance of behavior analytic research for improving skills in sports to reduce injury and improve athletic skill (Schenk & Miltenberger, 2019). Sports interventions designed by behavior analysts employ various forms of feedback such as verbal, auditory, and video to enhance sports performance. Verbal feedback consists of spoken feedback on performance that identifies correct components to be continued and incorrect components of performance to be improved (Schenk & Miltenberger, 2019). For example, Kladopoulos and McComas (2001) examined form training on foul-shooting performance and correct shooting form. Three female collegiate basketball players received verbal feedback on the task analysis for proper form. Once the participant made a practice shot, the researcher provided descriptive praise. The results showed all participants improved in correct form after the first session of the intervention. By the third session, all participants showed 100% correct form.

In auditory feedback, a sound (e.g., a click or beep) is delivered after successful performance of an athletic skill or specific step of a skill to improve performance levels (e.g., Quinn et al., 2015; 2017) For example, Quinn et al. (2017) used a multiple baseline design to evaluate auditory feedback delivered by peers to enhance a dance movement for six female jazz dancers. The peer provided a click when the student executed a dance movement correctly, while not providing feedback for incorrect movements. All six participants improved their performance on all dance movements. In another example, Fogel et al. (2010) evaluated TAG teach, a form of auditory feedback, to teach a golf swing for a female golfer, with no prior golf experience. When a skill was performed correctly it was 'tagged' with the clicker. In the beginning of each session, the researcher would review the previous sessions' tagpoints, to ensure each tagpoint would maintain. The resulted showed that the use of auditory feedback resulted in successful skill acquisition on four of the five skill sets.

Video feedback has been used in various sports performance studies. It utilizes a review of video footage of the participant performing the skill with praise and corrective feedback to improve performance levels (Schenk & Miltenberger, 2019). BenitezSantiago and Miltenberger (2015) used a series of multiple baseline designs across to three martial arts movements to evaluate video feedback for each of five adult participants. During the video feedback intervention, the participants were filmed attempting a specific movement and immediately viewed the video afterwards while receiving positive and corrective feedback from the instructor. The results showed that the skills for each participant increased to consistently higher levels. Video feedback plus practice was additionally implemented for three participants, resulting in even higher levels of performance. In another study, Kelley and Miltenberger (2016) used a multiple baseline design to evaluate video feedback for improving horseback riding skills for four female advanced beginning riders. The participants were filmed attempting a specific movement and viewed the video afterwards, when they received positive and corrective feedback from the instructor. Video feedback was shown to be successful in increasing the correct behaviors for all participants.

Proper running form is important for injury prevention and can promote continued engagement in running as a long-term form of exercise. A behavior analytic account of video feedback has been shown to be effective with a number of sports, but it has not been evaluated for improving running form. Video feedback may be useful because both the runner and trainer has a tangible product from which they can view the runner's form and concur with the required changes. By contrast, verbal feedback alone relies on a fleeting stimulus retained in the observer's memory, and the interpretation of the trainer's verbal instructions by the runner. Therefore, the purpose of this study is to evaluate video feedback for improving the running form of experienced runners.

Chapter Two: Method

Participants and Setting

The participants utilized for this study were three adults averaging 24 years old, experienced runners recruited from a local CrossFit gym and/or word of mouth. James was a 22-year-old man, who engages in aerobic exercise for about 60 minutes every day for the past 12 months. Tiffany was 25-year-old woman, who has been running around three miles, twice a week for five consecutive months. Kelly was a 24-year-old woman, who has been around two miles, twice to three times a week for six consecutive months. All participants answered yes to the question, "Do you think it would be valuable to improve your running form?" on the pre-intervention questionnaire. Experienced runners are individuals who run two to three times a week for 3 consecutive months, which was verbally reported to the principal researcher. The participants were asked to fill out a pre-intervention questionnaire to include only those who wanted to improve running form and to exclude anyone that had had a history of ankle-related injuries, any fainting episodes or lightheadedness during or after a run and/or have ever had any physical or medical problems related. The study was conducted outside on a sidewalk near local CrossFit gym. A flyer was passed out to the CrossFit athletes that were interested in being a part of the study and the athletes were allowed to take extra flyers to hand out to friends and family members that may be interested in participating in the study. Participant inclusion criteria was specified to each participant and were evaluated on the percentage of correct steps using the task analysis and were required to score 70% or less at baseline. Any participant that scored higher was not included in the study. Any participant who had a history of ankle-related injuries, any fainting episodes or lightheadedness during or after a run and/or have ever had any physical or medical problems related was not included in the study. In order to avoid any fainting/lightheaded episodes while running for this study. The institutional review board provided approval to conduct this study. The research assistant affiliated with this study received Collaborative Intuitional Training Initiative Program Certification (C.I.T.I); which indicates they completed an online training course on learning about the ethical code for conducting research with human subjects (Citi Program, n.d.).

Materials

An iPhone® 11 was utilized for video recording. A tripod was used to hold and stabilize the iPhone® 11 while video recording. A Yammax® SW-200 pedometer was utilized to count the steps the participants engaged in after each assessment; in order to calculate if stride length increased with the presentation of the intervention. Schneider et al., 2004 states that the Yammax® SW-200 is suitable for research purposes because the mean values the pedometer tested did not differ from the criterion. The Dartfish® application was utilized to display video recordings in slow motion, and visually display angles in degrees in order to score the steps in the task analysis. A 9-step task analysis was created by reviewing relevant literature on correct running form (Dunne, 2021; Geoghegan, 2019; Souza, 2016) and breaking running form into observable and measurable steps.

Target Behaviors and Data Collection

The dependent variable was the demonstration of correct steps from a 9-step task analysis of correct running form (as shown in Appendix A). The steps in the task analysis were analyzed and taken from a peer reviewed article (Souza, 2016). As illustrated, the foot placement strike of a runner should either be a forefoot strike or mid-foot strike. Forefoot strike is when the balls of the feet make contact with the ground. A mid-foot strike is when the middle part of the foot makes contact with the ground. Elbows should be at an 80-to-100-degree angle while the arms are maintained parallel to the body and there is no crossover to the midsection. Arms should be swinging from the shoulder while bringing elbows back. Shoulders should also be relaxed and have no tension or shoulders raising, while also having relaxed hands, displaying no fists. Vertical or flexed tibia is recommended, which is keeping the knee straight forward and containing a slight bend. Lastly, the participant should be running with a forward trunk lean, meaning the body is leaning forward in comparison to being upright.

The Dartfish® app was among the most commonly used, and the reliability of this app ranged from very good to excellent. There are at least two reviews evaluating the status of the validity and reliability of the more recently available two-dimensional video technology (e.g., smart phone cameras and applications) for measuring and analyzing running movements (de Oliveira et al., 2019; Michelini et al., 2020; Mousavi et al., 2020). Although de Oliveira et al. (2019) found very good to excellent reliability and validity across studies, they reviewed only eight studies in total, and only two studies assessed validity. Michelini et al.'s (2020) results were not as favorable, finding variable outcomes from poor to excellent measures. They evaluated 30 articles and several gait parameters assess by the technology. Further, based on the results of their review, the authors recommended the use of Dartfish® for future studies.

Both reviews suggested more evaluations on the validity of 2D video compared to the gold-standard 3D technology should be done. However, the best outcomes of reliability and validity were found when using a tripod for sagittal plane evaluations (Michelini et al, 2020) and for kinematics in the lower extremities, such as foot-strike patterns (de Oliveira et al., 2019; Mousavi et al., 2020). Despite some current shortcomings from the available data, two-dimensional video analysis is an efficient, practical, and accessible tool for assessing running form. As such, the researcher utilized a tripod and mobile phone to record the runner's sagittal plane movements from the side perspective, as the participant runs across the visual field of the camera. The participant ran 50m before coming into the video camera frame, so the runner was in a relaxed gait. Running form was scored from the video, using the task analysis to calculate the percentage of correct steps completed. This was done by reviewing each video utilizing the Dartfish® application in slow motion and visually analyzing the runner form angles. A "Y" (i.e., yes) was scored if the participant performed the step at criterion and an "N" (i.e., no) was scored if the participant performed the step incorrectly. This process occurred after each assessment session in baseline and intervention.

Interobserver Agreement

A second observer collected data for a 35% of the sessions to calculate interobserver agreement (IOA). The percentage of agreement was calculated by dividing the number of steps both observers agreed upon by the total number of steps, and then multiplying by 100. The research assistants were trained to collect data by utilizing the video recordings of the participants while having a visual copy of the task analysis and access to the Dartfish® application. The principal investigator (PI) first showed the research assistant a video of correct running form and verbally provided feedback on whether the research assistant should score the step as "Y" or "N" on the data sheet. The research assistant collected reliability data once they achieved at least 90% reliability with the PI during training. If reliability fell below 80% during the study, the PI evaluated the source of the disagreements. If disagreements appeared to have occurred from observer drift, then a booster session for reliability training was provided. IOA was calculated to be 100% across 38% of sessions for James, 33% of sessions for Tiffany, and 33% of sessions for Kelly.

Social Validity

Social validity of the intervention was measured by a questionnaire utilizing a 5-point Likert-type scale (1 = *Strongly disagree* to 5 = *Strongly agree)* and one open-ended question. The questionnaire (Appendix B) was given to the participants following the completion of the study. The questionnaire evaluated the participants' perceptions of the effectiveness of the intervention, the ease of the intervention, and if they would recommend it to others.

Treatment Integrity

Treatment integrity data were collected by a research assistant in 50% of the sessions across participants to ensure procedures were implemented correctly by the researcher (see Appendix C). The research assistant was trained on the experimental procedures prior to data collection by utilizing the video recordings of the participants. They also had a visual copy of the treatment integrity checklist. Treatment integrity was calculated by diving the number of steps the researcher completed correctly by the number of steps in the treatment integrity checklist, and then multiplying by 100 percent. Treatment integrity was calculated to be 100% across all participants.

Experimental Design and Procedures

A nonconcurrent multiple baseline across participants design was utilized, consisting of baseline, intervention, and follow-up phases for each participant. The transition from baseline to intervention was staggered across the participants.

The principal investigator met with potential participants to explain the study, obtain informed consent and conduct an assessment to evaluate if a participant met the inclusion criteria. A preintervention questionnaire was given to participants in order to obtain information about how they felt about their running form and if they thought their running form needed improvement (as shown in Appendix D). The pre-intervention questionnaire also included questions regarding if the participant had any history of ankle-related injuries, if they had ever experienced any fainting episodes or lightheadedness during or after a run and/or had ever had any physical or medical problems related to running. Recording procedures were explained, and when the participant agreed to be in the study, they were asked to review and sign the consent form. A copy of the consent form (including the outline of procedures) was given to the participant. Participants were asked to wear the same shoes for the duration of the study. Sessions were conducted outside on a sidewalk near a local CrossFit gym and times varied depending on each participant's availability.

Baseline

The participant was given a pedometer and asked to run 100 m at a jogging pace, and the researcher stood at the 50-meter mark with the tripod holding the iPhone® 11. The researcher video recorded the participant as they crossed the visual field of the camera. The camera was facing the direction of the participant, and when the participant moved in front of the camera, the researcher slightly started shifting the camera to follow the participant's path. Video recording ceased once the participant's back was facing the camera. The participant did not see their videos and no feedback was given. After each run, the participant reported to the researcher the number shown on the pedometer.

Video Feedback

The video feedback phase was conducted in the same manner as baseline until the participant completed the run. Immediately after the run, the researcher approached the participant and provided video feedback on their running form. The researcher showed the participant their video in regular speed and in slow motion, displaying their running form and provided feedback on what steps were performed correctly or incorrectly, according to the 9-step task analysis. During feedback, the researcher provided descriptive praise for steps completed correctly, such as, “Nice job keeping your arms parallel” or “Good job using front foot strikes.” Corrective feedback was also provided for incorrect steps, such as, “Remember to lean forward” or “Try to think about moving forward.” The researcher provided feedback on all 9 steps of the task analysis for each video recorded practice run. These practice runs were repeated three times. After the third video feedback practice run, the researcher asked the participant to perform an assessment run, for which data was collected. After each assessment run, the participant would report to the researcher the number shown on the pedometer. As a whole, each session visit consisted of three run assessments, however before an assessment was conducted, three runs with video feedback occurred. After those three runs with video feedback, three run assessments were conducted and no feedback was given. The mastery criterion was met after three consecutive data points were 80% or higher.

Follow-up

Follow-up data were collected 1 to 7 weeks after the intervention. The procedures in this phase were identical to baseline.

Chapter Three: Results

Figure 1 shows the results of the study. All the participants scored lower than 70% at baseline and improved to 100% correct once the intervention was implemented. James scored an average of 55% in baseline however, he had a spike in the second assessment where he scored 66%. In the intervention session, James scored 88% in the first two assessments and then achieved 100% in the third assessment and maintained that score throughout the intervention phase. During the follow-up phase, James continued to participate for 7 weeks after intervention was terminated and he maintained 100%. We also measured meters per step in the study utilizing the pedometer count to evaluate if improving running form increased stride length. James averaged 1.27 m per step during baseline, 1.42 m per step in intervention, and 1.39m per step during follow-up. These data show that his stride length increased when he utilized correct running form.

Tiffany scored an average of 53.8% correct in baseline however, she had a dip to 44% on her ninth assessment. In the intervention phase, Tiffany went through three assessment sessions before achieving criterion. In assessments 10, 11 and 12 her scores were similar to her baseline scores. However, from assessment 13 and on her percentage correct increased and at assessment 19 she scored 100%. She maintained that score throughout the intervention phase. During the follow-up phase, Tiffany continued to participate for 6 weeks after intervention was terminated and she maintained 100%. Tiffany averaged 1.02 m per step during baseline, 1.09 m per step during intervention, and 1.11 m per step during follow-up. Tiffany's stride length also increased when she utilized correct running form.

Kelly scored an average of 52.8% in baseline. In the first three assessments she scored 44% but then scored 55% for the remaining baseline assessments. In intervention Kelly scored 100% right after video feedback. She maintained that score throughout the intervention phase. During the follow-up phase, Kelly continued to participate for 1 week after intervention was implemented and she maintained 100%. Kelly averaged 1.02 m per step during baseline, 1.12 m per step during intervention, and 1.10 m per step during follow-up. Kelly's stride length also increased when she utilized correct running form.

The social validity results showed that all the participants stated they enjoyed being a part of this study, they found it easy to participate in the intervention, found the intervention to be helpful, and that they would recommend this intervention to others. James stated that he enjoyed being a part of this study because it helped him improve his running form and prevent any future injuries. He also stated that he found it helpful and beneficial for his physical health because he can now run faster with an improved running technique which has resulted in longer, less aggravating runs. Tiffany stated that she was able to generalize the skills she learned in this study across various different setting like running on the treadmill. Kell stated that she found this study to be very helpful and has improved her running form in a short period of time.

Chapter 4: Discussion and Limitations

The results of this study showed video feedback to be effective in improving running form for three adults. All the participants reached criterion following video feedback and maintained their correct form throughout their participation in the study. These findings add to the current literature because there is no single subject design research that evaluated video feedback to improve running form. There are a number of studies that have evaluated 3D technology to improve running form, typically on an indoor treadmill (Diebal, 2011; 2012; Messier & Cirillo, 1989; Miller et al., 2020). This study utilized 2D technology and evaluated running form outside where the participants typically ran. This study also adds to the literature on the Dartfish® application, demonstrating that it is an efficient, practical, and accessible tool to evaluate running form (de Oliveira et al., 2019; Michelini et al., 2020; Mousavi et al., 2020). Participants in this study reported that they were more mindful of their running form after participating in the video feedback intervention; they actively thought about their running form whenever they engaged in any running activity. They also reported that they wondered how they looked when running at that moment, in order to see if they were engaging in correct running form.

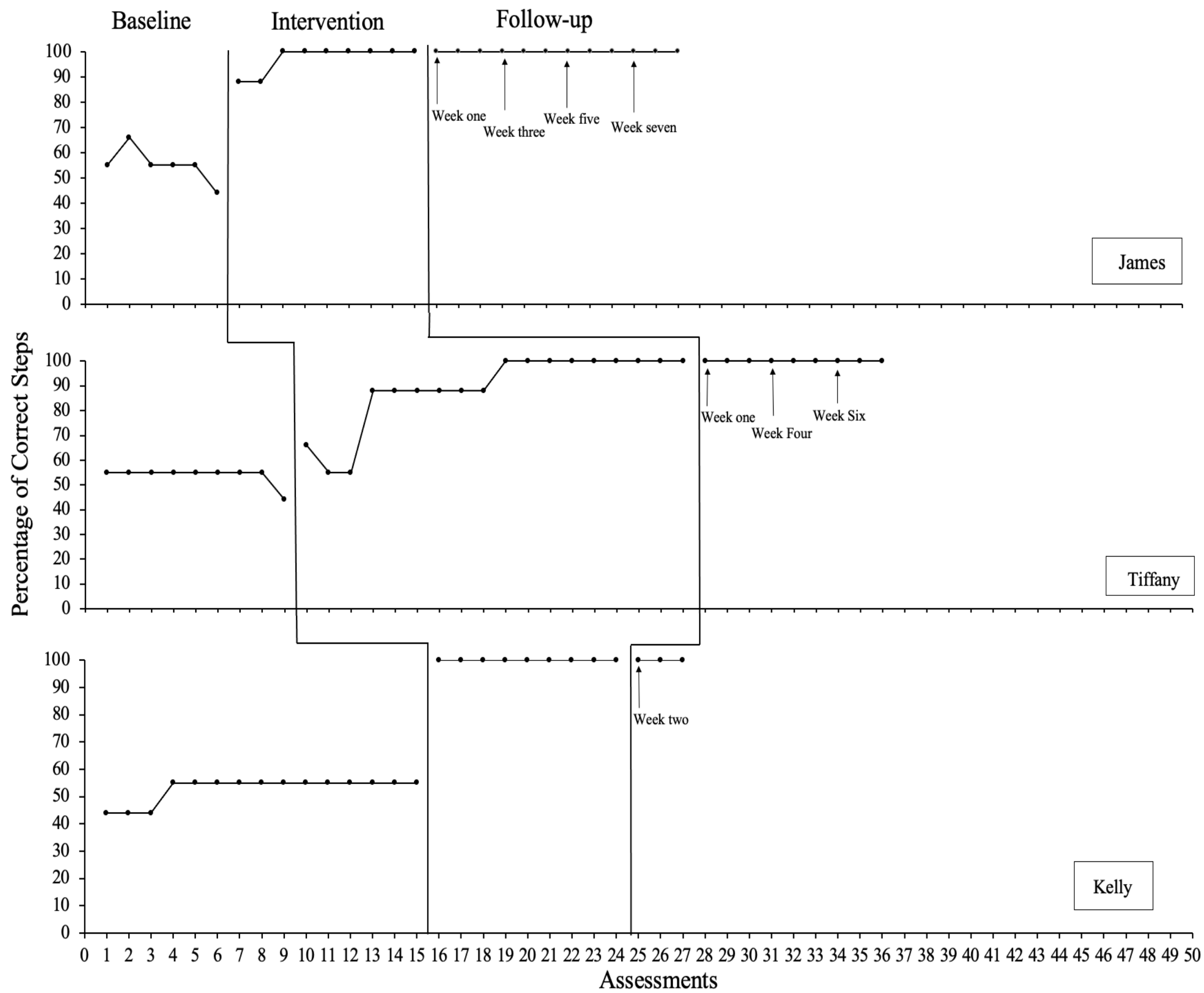
In addition to being effective, the video feedback intervention in this study was an efficient and easy procedure to administer. Each assessment took about 2 min to complete including the feedback session, meaning a whole data collection and intervention session took no longer than 15 min. Videotaping and then immediately showing the participant their video was a quick and easy process, especially because the researcher met the participant halfway allowing them to catch their breath and/or rest while receiving feedback. Utilizing an iPhone 11 also made the process easy because the video recording and video playback functions on an iPhone 11 are easy to use. Furthermore, all the participants in the study utilized an iPhone so they were already familiar with how the screen works and did not have any complications looking at their video while the researcher was giving them either corrective or positive feedback. Based on the social validity results, the participants enjoyed being a part of the study. The participants also reported that it was easy to participate in this intervention; they also found the intervention helpful. The social validity results also showed that the participants would recommend this intervention to others. James reported that being a part of this study improved his running form and prevented any future injuries. He also found it helpful and beneficial for his physical health because he can now run faster with an improved technique which has resulted in longer and less aggravating runs.

One limitation found in this study is that the pedometers being utilized in the study were sensitive to movement other than steps and thus placing the pedometer on the hip before running sometimes counted a few steps. To counteract this problem, the researcher told the participants to make sure to restart their pedometers before starting a new run. The researcher also asked the participants to stop right at the 100-meter mark and tell the researcher their total number of steps right when the run finished. Another potential limitation in this study is that reactivity could have been a factor influencing correct running form. The participants knew they were being videotaped and analyzed for their correct running form during the intervention and follow-up phase. Therefore, the participants could be engaging in correct running form when being videotaped; however, they may be utilizing incorrect running form when alone. Future research should evaluate reactivity through surreptitious observations of running. Another limitation is that we only recorded running form during short runs. This study evaluated running form when the participant was running 100-meters; however, it is not known whether that correct running form would maintain when running longer distances. Future research should also evaluate the reactivity limitation this study has by having a camera evaluating the participants running form but then having another camera hidden towards the end of their run to assess if correct running form is occurring during the whole run or only when in the visual field of the camera.

Future research should evaluate if correct running form allows a runner to finish their runs in less time. This study measured meters per step indicating whether the participants stride length either decreased or increased when utilizing correct running form, and the results showed that the participant's stride length did increase. However, this study did not measure if the runs were completed in less time during the feedback phase compared to the baseline phase. It would be interesting to evaluate if correct running form decreases a runner's time in a specific distance to see if they are running faster. Future research should also evaluate if correct running form generalizes to various running locations. This research study took place outside on a sidewalk, the results showed that correct running form maintained after several weeks of running outside. It would be interesting to evaluate if correct running form that is evaluated outside on a sidewalk can generalize to various locations such as on grass or an indoor treadmill. One final research question could be whether improved running form led to a decrease in perceived exertion during the run. If the runner perceived the run to be less effortful, they might be more likely to run or more likely to run longer. Some researchers have shown that music while running leads to a decrease in the participants' ratings of perceived exertion (RPE; Borg, 1982) during a run (Bigliassi et al., 2015: Nikol et al., 2018). It would be valuable to see if improved form also led to decreases in perceived exertion.

Figure 1

Percentage of Correct Steps in Running Form in Baseline, Video Feedback, and Follow-up Phases.



References

Agresta, C., & Brown, A. (2015). Gait retraining for injured and healthy runners using augmented feedback: A systematic literature review. *The Journal of Orthopaedic & Sports Physical Therapy*, *45*(8), 576–584. https://doi.org/10.2519/jospt.2015.5823

Arendse, R. E., Noakes, T. D., Azevedo, L. B., Romanov, N., Schwellnus, M. P., & Fletcher, G. (2004). Reduced eccentric loading of the knee with the pose running method. *Medicine and Science in Sports and Exercise*, *36*(2), 272–277. https://doi.org/10.1249/01.MSS.0000113684.61351.B0

Barker, J., McCarthy, P., Jones, M., & Moran, A. (2011). *Single-Case Research Methods in Sport and Exercise Psychology* (1st ed.). Routledge. https://doi.org/10.4324/978020386188

Benitezsantiago, A. S. & Miltenberger, R. G. (2015). Using video feedback to improve martial arts performance. *Behavioral Interventions, 31*(1), 12-27. https://doi.org/10.1002/in.1424

Bigliassi, M., León-Domínguez, U., Buzzachera, C. F., Barreto-Silva, V., & Altimari, L. R. (2015). How does music aid 5 km of running? *Journal of Strength and Conditioning Research*, *29*(2), 305–314. https://doi.org/10.1519/JSC.0000000000000627

Boecker, H., Sprenger, T., Spilker, M. E., Henriksen, G., Koppenhoefer, M., Wagner, K. J., Valet, M., Berthele, A., & Tolle, T. R. (2008). The runner's high: Opioidergic mechanisms in the human brain. *Cerebral Cortex*, *18*(11), 2523-2531. https://doi.org/10.1093/cercor/bhn013

Borg G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, *14*(5), 377–381.

Cantwell J. D. (1985). Cardiovascular aspects of running. *Clinics in Sports Medicine*, *4*(4), 627-640. https://pubmed.ncbi.nlm.nih.gov/3902253/

Clansey, A. C., Hanlon, M., Wallace, E. S., Nevill, A., & Lake, M. J. (2014). Influence of tibial shock feedback training on impact loading and running economy. *Medicine and Science in Sports and Exercise*, *46*(5), 973–981. https://doi.org/10.1249/MSS.0000000000000182

Crowell, H. P., Milner, C. E., Hamill, J., & Davis, I. S. (2010). Reducing impact loading during running with the use of real-time visual feedback. *The Journal of Orthopaedic and Sports Physical Therapy*, *40*(4), 206–213. https://doi.org/10.2519/jospt.2010.3166

Daoud, A. I., Geissler, G. J., Wang, F., Saretsky, J., Daoud, Y. A., & Lieberman, D. E. (2012). Foot strike and injury rates in endurance runners: a retrospective study. *Medicine and Science in Sports and Exercise*, *44*(7), 1325–1334. https://doi.org/10.1249/MSS.0b013e3182465115

Davis, I. S., & Futrell, E. (2016). Gait retraining: Altering the fingerprint of gait. *Physical Medicine and Rehabilitation Clinics of North America*, *27*(1), 339–355. https://doi.org/10.1016/j.pmr.2015.09.002

de Oliveira, F., Fredette, A., Echeverría, S. O., Batcho, C. S., & Roy, J. S. (2019). Validity and reliability of 2-dimensional video-based assessment to analyze foot strike pattern and step rate during running: A systematic review. *Sports Health*, *11*(5), 409–415. https://doi.org/10.1177/1941738119844795

Diebal, A. R., Gregory, R., Alitz, C., & Gerber, J. P. (2011). Effects of forefoot running on chronic exertional compartment syndrome: a case series. *International Journal of Sports Physical Therapy*, *6*(4), 312–321. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230159/

Diebal, A. R., Gregory, R., Alitz, C., & Gerber, J. P. (2012). Forefoot running improves pain and disability associated with chronic exertional compartment syndrome. *The American Journal of Sports Medicine*, *40*(5), 1060–1067. https://doi.org/10.1177/0363546512439182

Dunne, J. (2021, March 7). *Proper Running Technique: Six Ways to Run More Efficiently*. Kinetic Revolution - Run Strong, Injury Free - Running Blog. https://www.kinetic-revolution.com/running-technique-6-ways-to-improve-efficiency/.

Fogel, V. A., Weil, T. M., & Burris, H. (2010). Evaluating the efficacy of TAGteach as a training strategy for teaching a golf swing. *Journal of Behavioral Health and Medicine, 1*(1), 25-41. http://dx.doi.org/10.1037/h0100539

Geoghegan, C. (2021, July 15). *How to run properly: Running technique for beginners*. Run With Caroline. https://www.runwithcaroline.com/how-to-run-properly/

Goss, D. L., & Gross, M. T. (2013, October). A comparison of negative joint work and vertical ground reaction force loading rates in chi runners and rearfoot-striking runners. *Journal of Orthopaedic & Sports Physical Therapy, 43*(10), 685-692. https://doi.org/10.2519/jospt.2013/4542

Guiney, H., & Machado, L. (2013). Benefits of regular aerobic exercise for executive functioning in healthy populations. *Psychonomic Bulletin & Review, 20*(1), 73–86. https://doi.org/10.3758/s13423-012-0345-4

Heiderscheit, B. C., Chumanov, E. S., Michalski, M. P., Wille, C. M., & Ryan, M. B. (2011). Effects of step rate manipulation on joint mechanics during running. *Medicine and Science in Sports and Exercise*, *43*(2), 296–302. https://doi.org/10.1249/MSS.0b013e3181ebedf4

Kelley, H., & Miltenberger, R. G. (2016). Using video feedback to improve horseback riding skills. *Journal of Applied Behavior Analysis, 49*, 138–147. https://doi.org/10.1002/jaba.272

Kladopoulos, C.N. and McComas, J.J. (2001). The effects of form training on foul-shooting performance in members of a woman's college basketball shooting. *Journal of Applied Behavior Analysis, 34*(3), 329-332. https://doi.org/10.1901/jaba.2001.34-329

Kleindienst, F.I., Campe, S., Graf, E., Michel, K., & Witte, K. (2007). Differences between fore and rearfoot strike running patterns based on kinetics and kinematics. *25 International Symposium on Biomechanics in Sports.* https://ojs.ub.uni-konstanz.de/cpa/article/view/451

Kumar, D., McDermott, K., Feng, H., Goldman, V., Luke, A., Souza, R. B., & Hecht, F. M. (2015, January 26). Effects of form-focused training on running biomechanics: A pilot randomized trial in untrained individuals. *American Academy of Physical Medicine and Rehabilitation, 7*(8), 814-822. http://dx.doi.org/10.1016/j.pmrj.2015.01.010

Lange, D. (2020, November 16). *Running & jogging – Statistics & facts*. Statista. https://www.statista.com/topics/1743/runningandjogging/#:~:text=Running%20is%20on%20of%20the,in%20the%20U.S.%20in%202017.

Messier, S. P., & Cirillo, K. J. (1989). Effects of a verbal and visual feedback system on running technique, perceived exertion and running economy in female novice runners. *Journal of Sports Sciences*, *7*(2), 113–126. https://doi.org/10.1080/02640418908729830

Michaud, T. C. (2016). Should you change an athlete's natural running form? *Journal of the American Medical Athletic Association, 29*(3), 11-13. http://www.dynamicchiropractic.ca/mpacms/dc_ca/article.php?id=57423

Michelini, A., Eshraghi, A., & Andrysek, J. (2020). Two-dimensional video gait analysis: A systematic review of reliability, validity, and best practice considerations. *Prosthetics and Orthotics International*, *44*(4), 245–262. https://doi.org/10.1177/0309364620921290

Miller, E. M., Crowell, M.S., Morris, J.B., Mason, J.S., Zifchock, R., & Goss, D. (2020, November 20). Gait retraining improves running impact loading and function in previously injured U.S. military cadets: A pilot study. *Military Medicine*. https://doi.org/10.1093/milmed/usaa383

Mousavi, S. H., Hijmans, J. M., Moeini, F., Rajabi, R., Ferber, R., van der Worp, H., & Zwerver, J. (2020). Validity and reliability of a smartphone motion analysis app for lower limb kinematics during treadmill running. *Physical therapy in sport: Official Journal of the Association of Chartered Physiotherapists in Sports Medicine*, *43*, 27–35. https://doi.org/10.1016/j.ptsp.2020.02.003

Nikol, L., Kuan, G., Ong, M., Chang, Y. K., & Terry, P. C. (2018). The Heat Is On: Effects of Synchronous Music on Psychophysiological Parameters and Running Performance in Hot and Humid Conditions. *Frontiers in Psychology*, *9*, 1114. https://doi.org/10.3389/fpsyg.2018.01114

Quinn, M. J., Miltenberger, R. G., & Fogel, V. A. (2015). Using TAGteach to improve the proficiency of dance movements. *Journal of Applied Behavior Analysis*, *48*(1), 11–24. https://doi.org/10.1002/jaba.191

Quinn, M., Miltenberger, R., James, T., Abreu, A. (2017, September 7). An evaluation of auditory feedback for students of dance: Effects of giving and receiving feedback. *Behavioral Interventions*, *32*(4), 370– 378. https://doi.org/10.1002/bin.1492

Schenk, M., & Miltenberger, R. (2019). A review of behavioral interventions to enhance sports performance. *Behavioral Interventions, 34*(2), 248–279. https://doi.org/10.1002/bin.1659

Souza, R. B. (2016) An evidence-based videotaped running biomechanics analysis. *Physical Medicine and Rehabilitation Clinics of North America, 27*(1), 217-236. https://doi.org/10.1016/j.pmr.2015.08.006

Schneider, P. L., Crouter, S., & Bassett, D. R. (2004). Pedometer measures of free-living physical activity: comparison of 13 models. *Medicine and Science in Sports and Exercise*, *36*(2), 331–335. https://doi.org/10.1249/01.MSS.0000113486.60548.E9

van Gent, R. N., Siem, D., van Middelkoop, M., van Os, A. G., Bierma-Zeinstra, S. M., Koes, B. W., & Taunton, J. E. (2007). Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *British Journal of Sports Medicine*, *41*(8), 469–480. https://doi.org/10.1136/bjsm.2006.033548

van Mechelen W. (1992). Running injuries. A review of the epidemiological literature. *Sports Medicine (Auckland, N.Z.)*, *14*(5), 320–335. https://doi.org/10.2165/00007256-199214050-00004

Appendix A

Task Analysis of Correct Running Form

Observable Behavior	Yes	No
1. Forefoot strike: Foot strikes the ground with the balls of feet Mid-foot strike: Foot strikes the ground with the middle of the foot/arch (Souza, 2016)		
2. Keep elbows at an angle range of 80-100 degrees when swinging arms (Dunne, 2021; Geoghegan, 2019)		
3. Arms are kept parallel to the body, no crossing over the mid-section (Geoghegan, 2019)		
4. Arms swinging from the shoulder, avoid any movement from the elbows (Geoghegan, 2019)		
5. Bringing/swinging elbows back from the body and forward to the body, instead of moving elbows from the body forward and back to the body (Dunne, 2021; Geoghegan, 2019)		
6. Relaxed shoulders, keeping them in a neutral position, parallel to the collar bone, while avoiding high shoulders, bringing the shoulders near the ears, while running (Dunne, 2021)		
7. Relaxed hands- having slightly open hands while avoiding making a tight fist (Dunne, 2021; Geoghegan, 2019)		
8. Vertical or flexed tibia - keeping the knee forward and keeping the knee in a slight bend (Souza, 2016)		
9. Running with a forward trunk lean, having the shoulders forward (Souza, 2016)		

Appendix B

Social Validity Questionnaire

Instructions: For the next set of questions, there are no right or wrong answers. Simply respond to each item as honestly as you can.

1. I enjoyed being a part of this study.

Strongly Disagree 1 2 3 4 5 *Strongly Agree*

2. I found easy to participate in the intervention.

Strongly Disagree 1 2 3 4 5 *Strongly Agree*

3. I found the intervention to be helpful.

Strongly Disagree 1 2 3 4 5 *Strongly Agree*

4. I would recommend this intervention to others.

Strongly Disagree 1 2 3 4 5 *Strongly Agree*

5. Provide any comments you would like to share about your participation in this study

Appendix C

Treatment Integrity Form

Baseline	YES	NO
1. The participant was asked to run at a jogging pace		
2. Researcher recorded front and side view while participant runs		
3. Researcher will be facing the visual field with iPhone® 11 at the cement platform		
4. No feedback was given throughout session about form		
Video Feedback Training Trials		
1. The participant was asked to run at a jogging pace		
2. Researcher recorded front and side view while participant runs		
3. Researcher will be facing the visual field with iPhone® 11 at the cement platform		
4. The researcher showed the participant the performance stills of the TA steps on Dartfish®		
5. The researcher provided feedback on TA step 1		
6. The researcher provided feedback on TA step 2		

7. The researcher provided feedback on TA step 3		
8. The researcher provided feedback on TA step 4		
9. The researcher provided feedback on TA step 5		
10. The researcher provided feedback on TA step 6		
11. The researcher provided feedback on TA step 7		
12. The researcher provided feedback on TA step 8		
13. The researcher provided feedback on TA step 9		
Follow-up		
1. The participant was asked to run at a jogging pace		
2. Researcher recorded front and side view while participant runs		
3. Researcher will be facing the visual field with iPhone® 11 at the cement platform		
4. No feedback was given throughout session about form		

Appendix D

Preintervention Questions

Instructions: For the next set of questions, there are no right or wrong answers. Simply respond to each item as honestly as you can.

1. Do you think it would be valuable to improve your running form?

2. Do you have any history of any ankle-related injuries? If so, please describe the injury and what caused it?

3. Have you ever had any fainting episodes or lightheadedness during or after a run?

4. Have you ever had any physical or medical problems related to running?