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Pike, Duncan Christopher

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Investigating the Effects of Visually Augmented Video Feedback on Performance of an Ice Hockey Skating Skill

By Duncan C. Pike

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This volume is dedicated to my
parents, without whose support it
could not have been completed.

Abstract

The study tested the effects of video replays enhanced with graphic, kinematic feedback on a targeted aspect of the hockey skating stride. A single subject, multiple baseline, across participants design was used. Participants were 4 varsity hockey players. Feedback was a measurement of the supporting knee angle at extension of the thrusting leg and a visual representation of an optimal angle, superimposed over video replay. Feedback immediately followed alternate trials, during several sessions over 5 weeks. The targeted change was a lower angle of initial knee flexion. Mean and level of initial knee flexion reduced after intervention in all participants. Changes were observed to occur at the second session of the intervention phase.

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1 INTRODUCTION

The acquisition and development of a motor skill is a complex process. A coach's goal is to facilitate skill acquisition. Of the many possible strategies, demonstration is the most commonly used method of presenting movement information in sport settings (Williams & Hodges, 2005). Demonstrations can take several forms, including live and video demonstrations. In motor learning, this approach is termed *observational learning.* This study examined a method of enhancing video demonstrations by adding *knowledge of performance* (KP) in the form of superimposed measurements on the original video. KP is a form of augmented feedback that gives a learner information about how his actions led to his result (Magill, 2004).

An established theory holds that an observer of a movement perceives, extracts and records the most basic level of information about that movement, which is a coordination pattern of the limbs and joints involved (e.g. McCullagh & Weiss, 2001; Scully 1986; Scully & Newell 1985). This *cognitive representation*, which is often initially established by observation, is the programme used by the central nervous system in the execution of the movement. Observation of a movement has been shown to evoke brain activity similar to that involved in executing the movement (Beauchamp, Lee, Haxby, & Martin, 2003; Hodges, Williams, Hayes, & Breslin, 2007; Vogt & Thomaschke, 2007), solidly supporting the theory that observation and execution of motor skills are cognitively linked. Both the nature of the data that is recorded from visual observations and its interaction with the motor system have been shown to affect the overt execution of motor skill (e.g. Hayes, Hodges, Scott, Horn, & Williams, 2007, Scully & Newell). Through film and video observation, the cognitive representation can be augmented, improved and refined (Burroughs, 1984; Christina, Barresi, & Shaffner, 1990; Salmela & Fiorito, 1979). Because the cognitive representation is the data employed in skill execution, as the representation improves so will performance. Therefore, refining the cognitive model through observational learning will improve the execution of the movement. As the execution improves, observation can accommodate more precise corrections, and the cognitive model is successively refined.

It is well established that knowledge of performance (KP) improves motor performance of a skill (Kernodle & Carlton, 1992; Magill, 1993; Magill & Schoenfelder-Zhodi, 1996). KP is a form of extrinsic, or augmented, feedback (Schmidt & Wrisberg, 2000). If executing a skill depends on the quality of the cognitive representation, and KP improves execution, it is logical to suggest that KP can be used by a learner to improve his cognitive representation. In this case, KP must be appropriately filtered and organised based upon its relevance to a specific aspect of an entire skill. The KP must be coded into the cognitive model of the skill. KP (and *knowledge of results*, or KR), however, can normally be delivered only following a trial. Where task-intrinsic feedback during a performance is inextricably linked to its position within the coordination pattern and therefore within the cognitive model, extrinsic feedback must be purposefully integrated with the model. The major advantage of intrinsic over extrinsic feedback is that intrinsic feedback is experienced while the cognitive representation of the skill is actively being accessed (i.e. during performance), whereas extrinsic feedback is normally delivered when the cognitive representation is not active (i.e. after performance).

It can be theorised that KP will be more efficiently and effectively coded into the cognitive representation, if said KP is presented as part of a video replay. Since the cognitive representation appears to be accessed during observation of a movement, presenting KP as part of a unified, visual presentation, affixes the KP to its appropriate position in the actively perceived coordination pattern. Therefore, new information might not need to be consciously 'filed.' Superimposing KP onto video of a learner's performance would, then, augment and improve the cognitive representation of the skill and therefore improve the quality of future performance. Such a theory would suggest that the use of this visually augmented video feedback would be related to targeted changes in the performance of a skill.

Dartfish video analysis software allows the delivery of visually augmented video feedback in a practical, field setting with minimal intrusion. The software is already in wide use by many high level sport coaches and athletes (Bartoli, Dala, & Horaud, 2004; Baudry, Leroy, & Chollet, 2006; Demeris, et al., 2002; Hars & Calmels, 2007; Hayes, Hodges, Scott, et al., 2007; Hodges & Williams, 2007; Kokaram, et al., 2006; Sheppard, 2006; Thomas & Stratton, 2006; Williams & Hodges 2005), and is also being used in clinical and research applications (Miller & Kang, 2007; Petersen, Hansen, Aagaard, & Madsen, 2007; van Vuuren-Cassar & Lamprianou, 2006; Womersley & May, 2006), including use by NASA to test astronauts' space suits (Abercrombie, Thaxton, Onady, & Rajulu, 2006). Despite this proliferation, a search of relevant literature returned only a single study involving any form of feedback that unified modelling and KP in a single, visual presentation. Using a group design (n=16), Baudry et al. (2006) showed that participants experiencing that unified presentation exhibited greater improvement than a control group. With Dartfish, feedback is tailored to the individual. This makes a single subject design appealing, since it allows the close examination of of participants' responses to self-specific feedback. Single-subject analysis allows closer examination of individual participants, which can reveal clues to direct future researchers as they investigate those next questions.

A systematic (rather than direct) replication of Baudry et al.'s study, investigating Dartfish effects on a skating skill with a single subject design, was therefore selected. The most researched skill in ice hockey skating is the forward stride; its important variables can be analysed easily in two dimensions. The pommel horse circle, studied by Baudry et al., is a serial skill that requires a great deal of upper body strength. The forward skating stride in ice hockey is a continuous skill that primarily involves the lower body. The pommel horse circle is a form-oriented skill, and the forward skating stride is a goal-oriented skill. Like Baudry et al.'s study, the present one investigated whether feedback provided with Dartfish resulted in a targeted change in performance.

The purpose of this study was to determine if the delivery of knowledge of performance, through the use of Dartfish video analysis software resulted in a targeted change in performance on a specific, kinematic variable during forward skating. It was hypothesised that this intervention would lead to the achievement of the targeted change by each participant.

1.1 Key Terms

Augmented Feedback: Any extrinsic information given to a learner about his performance of a motor skill (Schmidt & Lee, 1999).

Changes in magnitude: Changes in mean and changes in level pertain to the magnitude of a change in performance (Kazdin, 1982).

Changes in rate: Changes in trend and latency of the change pertain to the rate of change in performance (Kazdin, 1982).

Cognitive representation: The abstract model of a motor skill, derived from the skill's coordination pattern, and stored in the learner's memory.

Dartfish ProSuite v. 4.0.9.0 (Dartfish, 2006): A commercial software programme with the ability to capture video to a computer hard disc, and from that video to measure displacements, angles and time, and to calculate their derivatives (e.g. velocity). It is used primarily in delivering KP or KR to the performer of a motor skill, normally by superimposing graphics and/or measurements upon the video of a recent performance. Dependent on the available computer hardware, Dartfish can be used to present KP and KR either immediately following a performance, or after a more lengthy analysis. It is most used by coaches, but also by researchers and healthcare professionals. In this document the terms *Dartfish, Dartfish ProSuite*, *Dartfish system*, *Dartfish software*, etc. are interchangeable.

Demonstration: Any visual presentation of a motor skill meant to show, to someone attempting to learn it, the correct way to perform that skill (Schmidt & Wrisberg, 2000).

Feedback: Any information a learner acquires about his performance or its results.

Intrinsic Feedback: Intrinsic information about a motor skill, perceived by the performer. It is also called proprioceptive feedback or sensory feedback (Schmidt & Lee, 1999).

Knowledge of Performance (KP): "A category of augmented feedback that gives information about the movement characteristics that led to a performance outcome" (Magill, 2004, p. 384).

Latency of the change: The time between the change of phase or experimental condition, and change in performance (Kazdin, 1982). In this study, it is the period of time between the introduction of the Dartfish intervention and the change in performance on the targeted variable.

Learning (motor learning): “A set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for motor skill” (Schmidt & Lee, 1999, p. 416).

Level: Changes in level are distinct changes, that occur at an identifiable time, in the magnitude of scores on a variable (Kazdin, 1982).

Limits of Agreement: A statistical method that indicates absolute reliability of two sets of scores, based on mean differences and confidence intervals (Atkinson & Nevill, 1998; Rankin & Stokes, 1998).

Observational Learning: Learning a motor skill be observing demonstrations of the skill (Magill, 2004).

Performance (motor performance): Qualitative and quantitative characteristics of the overt execution of a motor skill.

Vicon Motus (Vicon Motion Systems, Inc., 2006): A commercial software programme with the capability to make indirect measurements of kinematic variables from video. It also includes sophisticated data smoothing and filtering techniques to compensate for measurement error and reveal true signals accurately. This makes it useful for purposes such as biomechanical or medical research, and professional animation.

Video Feedback: Feedback, in this study KP, in the form of a video display of a motor performance.

Visually Augmented Video Feedback: Video feedback that has been augmented with additional, visual information not present in a regular video.

1.2 Limitations

1. Participants:

    A small sample of four participants was recruited only from the Lakehead University hockey team.

2. Research Environment:

    The ice-surface (hardness, cleaned or not cleaned, etc.) and lighting had the potential to vary due to environmental and maintenance conditions. These were beyond the researcher's control.

3. Scheduling:

    Data collection had to be coordinated around the participants' competition, training, and academic schedules, and availability of ice-time at a municipal facility that must accommodate many community groups.

4. Software Capabilities:

    Measurements made with Dartfish are limited to 2 dimensions.

1.3 Delimitations

1. Participants:

    The study was delimited to a sample of four, competitive, male ice hockey players from the Lakehead University varsity team.

2. Skill:

    Only the forward skating stride, at maximal speed, was investigated.

3. Research Environment:

   Because the skill can only be performed on an ice rink, and as participants were drawn from a single team, the location was delimited to that team's training facility.

4. Study Duration:

   The study was delimited to the remainder of the CIS hockey season, with data collection beginning in late January and concluding in mid-February.

5. Intervention:

   During intervention sessions, only the visually augmented, video feedback was presented, with no other information or instruction regarding performance. Feedback was given on only a single variable, and delivered at specific intervals during the session. Participants were only permitted to see video of their own performances, and only those trials upon which feedback was given. They were not shown their baseline, or no-feedback trials, and they were not shown any of the other participants' trials.

6. Research design:

   A single-subject, multiple-baseline, across-participants, AB design was utilised.

2 REVIEW OF LITERATURE

2.1 Feedback

Feedback is information perceived by a learner about his performance or its results. A performer can use feedback to make an effort to improve his ability to attain a desired outcome. For changes in performance to occur, the information contained within the feedback must be applied to the execution of the skill. There are primarily two types of feedback: (1) intrinsic feedback and (2) extrinsic or augmented feedback. Intrinsic feedback is that which is available to the learner directly, by virtue of the skill or the environment in which the skill is performed (Magill, 2004). Augmented feedback is from an external source; direction or instruction from a coach is an example of augmented feedback (Magill, 2004).

While intrinsic feedback is directly attached to its relevant position in a motor skill's execution, augmented feedback must be purposefully applied to the learner's cognitive representation of the skill. KP is a form of augmented feedback that provides information about how certain movements led to certain outcomes (Schmidt & Wrisberg, 2000). A learner can detect his own movements; therefore KP supplements intrinsic feedback, rather than adding information that was not available to the learner (Magill, 2004). Skills can be learned without KP, but many skills can be learned faster or learned at a higher level when intrinsic feedback is augmented by KP (Magill, 2004). Because KP, like most augmented feedback, is normally delivered following a performance, it is not directly attached to the aspect of the skill to which it is most relevant. That means that the learner must make the association between the KP he receives and the aspect of the skill to which it is relevant. If it is true that adjustments to the cognitive representation of a skill lead to changes in performance (McCullagh & Weiss, 2001;

Scully, 1986; Scully & Newell, 1985), then for feedback to lead to changes in overt execution of a skill, feedback must first lead to changes in the cognitive representation of the same skill.

2.2 Observational Learning

Demonstration, the most common form of instruction in sport settings (Williams & Hodges, 2005), is meant to facilitate observational learning (Magill, 2004). Observational learning is, just as the term suggests, learning by the observation of a performance of the skill to be acquired (Magill, 2004). This form of learning is broadly discussed in the literature as regards when and for whom it is effective, and how observational learning occurs as an internal process (Hodges et al., 2007; McCullagh & Weiss, 2001; Scully & Newell, 1985).

2.2.1 Characteristics of the Observer

Different types of observers show varying abilities to process and utilise visual data about motor performances. Though observational learning literature shows some bias toward children when it comes to initial learning of a skill (Ashford, Davids, & Bennett, 2007), it has been shown that children are, overall, less able to acquire correct movement patterns through observation than are adults (Wiese-Bjornstal & Weiss, 1992). Adults are likely able to adapt previously learned movement patterns to new constraints (Ashford et al.). As such, initial understanding of a coordination pattern, through observation, may not be as crucial. Children have less movement experience than adults and so benefit less from positive transfer from other skills (Schmidt & Wrisberg, 2000). To begin learning a totally new skill, the basic coordination pattern is obviously of utmost importance. Without any understanding of the movement, or frame of reference (e.g. a previously learned, similar skill) observational learning is arguably necessary. Because a child, with less movement experience than an adult, requires a more basic level of information about a movement, a simple presentation of the coordination pattern (as is theorised to occur in observational learning) would be of more importance for children. Adults are able to perceive point light displays more effectively than children (Wiese-Bjornstal & Weiss). Abernethy (1988) noted that adult performers are better able to predict upcoming movements from minimal, observed data than are younger performers. Abernethy and Russell (1987) found the same result in experts as opposed to novice performers, and that experts are able to perceive more useful information from earlier movements than are novices. These findings suggest that "efficient processing of movement information is partly dependent on experience" (Hayes, Hodges, Scott et al., 2007, p. 560).

If it is the information itself, and not the visual manner in which it is presented, that affects these outcomes, it may be the case that augmented modelling can have valuable effects in adults. When considering skill refinement, rather than initial learning, more specific information is needed as the learner already possesses a level of proficiency in the skill in question. There may simply be an inability of most learners to extract, process, and cognitively code information at such a precise level. Therefore, if that information is made obvious in a visual presentation, it is possible that this better facilitates observational learning. Indeed, if the learner can already process the coordination pattern from observation, then additional information included in the visual model will already be organised by its position in the coordination pattern. Therefore, if feedback is presented visually, in unison with the coordination pattern data inherent to video playback of a performance, a skilled performer may be better able to perceive, process, and implement that new information.

In many past studies, (e.g., Hayes, Hodges, Scott et al., 2007; Magill, 1993; Magill & Schoenfelder-Zhodi, 1996; Wiese-Bjornstal & Weiss, 1992) the participants have been children that are naïve performers of the skill to be acquired. With the findings that additional information can disrupt performance (Wiese-Bjornstal & Weiss) and that expert and adult performers are better able to perceive and process data (Abernethy & Russel, 1987), a study involving observational learning combined with KP for adult, experienced performers can be expected to produce different results than did previous studies involving children and/or inexperienced performers.

2.2.2 Characteristics of the Visually Perceived Data

As the data to be processed during observation is produced by a demonstration of the skill itself, it stands to reason that the nature of the skill being modelled (i.e. the nature of the data) would have an effect on the perception and processing of that data. Hodges et al. (2007) make an important demarcation between those movements in which a specific end-result is the primary goal and measure of success and skills where that measure is the characteristics of the movement itself. These can be called result-oriented goals and form-oriented goals, respectively. A result-oriented skill can be throwing a pitch at a certain location in baseball, whereas a form-oriented skill might be a specific spin in a figure skating routine. Any baseball spectator will note that many professional pitchers of similar success will have very different throwing motions. Figure skating spectators know just as well that skills in that sport must be performed the same way by all competitors to attain highest scores.

It seems that observational learning is more effective in form-oriented than in result-oriented skills (Ashford et al., 2007; Hodges et al., 2007). In young boys (mean age 6 years), Hayes, Hodges, Scott et al. (2007) found less accurate reproduction of the form of a modelled bowling skill when the participants performed the skill with a ball and an outcome-goal, as opposed to those participants performing the task without a ball so as to force focus on only the form. This result demonstrates that, even for an identical movement, the desired result perceived by the learner affects the way that visual information is utilised. So, if the learner does not see any advantage to the ultimate performance outcome from changing the form of his movements, there is little motivation for him to make efforts to change his movement patterns. Without such a motivation, the learner may not even pay the demonstration much attention (Clarke & Ste-Marie, 2007).

In the case of a gymnast, for example, it is clearly apparent that improved form will lead to better results because the result is an evaluation of form. For other athletes, it is not always clear. A familiar adage in many team sports is: when the game is over only the number of points matters and not how they were scored. For athletes in sports where the measurement is based only upon the result and not the process, motivation to change movement patterns may not always be present. Though form-oriented skills do see a greater effect from observational learning, this should not be taken to mean that result-oriented skills are not aided at all. The general trend in the literature is that point-light display and video-playback conditions have commonly shown better skill acquisition than have control conditions (Hodges et al., 2007). As Hayes, Hodges, Scott et al (2007) illustrated, the learner's perception is important to the effectiveness of learning. It also appears that these two types of information, or the nature of the observer's focus, give further contrast to result-oriented versus form-oriented tasks. It has been reported that end point data appears more useful for goal-driven tasks (Hayes, Hodges, Huys, & Williams, 2007). Therefore if the learner perceives the goal (or *a* goal) of the skill to be correct form, it can be argued that this will increase the effectiveness of observational learning, for that skill, upon that learner.

The nature of the model is another variable in the data presented by a demonstration. It has been shown that a model similar to the observer is more effective than a dissimilar model

(Hebert & Landin, 1994; McCullagh, 1986). Similar models are those closer in age and/or ability to the observer than a dissimilar model. It is argued that the learner relates more to similar model (Bandura, 1977; 1986; 1997), and obviously no model is more similar to the observer than the observer himself. Though results for motor performance (as is the trend in all observational learning research) are varied (Dowrick & Raeburn, 1995; Ram & McCullagh, 2003; Starek & McCullagh, 1999; Winfrey & Weeks, 1993), the literature has consistently shown self-models to increase the learner's self-efficacy (Clarke & Ste-Marie, 2007). In general, findings indicate that self-model and self-observation conditions are better than no-model (control) conditions (Kitsantas, Zimmerman, & Cleary, 2000; Zimmerman, 1989; 2000).

Shea and Wulf (1999) found that a condition of external focus, i.e. paying most attention to points outside the body, during practice is more effective in improving performance than is an internal focus, i.e. paying most attention to the body itself. Learners in the external focus group of Shea and Wulf's study continued to demonstrate improvement in performance even when feedback and instruction were removed. This supports the use of self-modelling, as this allows an external focus (on the video) while still giving feedback tailored to the learner's performance.

Providing KP in tandem with a visual demonstration may redefine a result-oriented skill, in the mind of the observer, as a form-oriented skill. Using a self-as-model demonstration allows the KP to be specifically relevant to the observer's performance and may also, as previously explained, improve both the observer's perception of the model as relevant, and the observer's self-efficacy.

2.2.3 The Cognitive Representation

To suggest that every learner absorbs the entirety of every demonstration is counterintuitive. If photographic memories are rare, one imagines that videographic memories must be as well. Both the sheer amount of information that would need to be stored in memory and the common knowledge that the human memory is imperfect make this idea improbable. Beside this, if learners retained every detail of the skill upon a demonstration, they would surely emulate the demonstration nearly perfectly in short order. With complex motor skills, this is not the case. What occurs, rather than total absorption of all visual information, is a reduction of the movement data to its most simple form: a coordination pattern. "The visual system is thought to minimise relative motion and thereby recognise the movement pattern" (Scully & Newell, 1985, p. 180). The data is not stored as videographic data, but as an abstraction in memory representing the skill, which Scully and Newell termed a *perceptual blueprint.* Like a blueprint, the cognitive representation must begin with a more basic sketch, and be reviewed and refined as it is developed, until it meets with the architect's approval.

While it may yet be debated precisely what information is recorded by the observer in a given circumstance, and how useful that information ultimately is, it is becoming quite definite that some interaction between the motor and visual systems is present. The cognitive mechanism of translating observation into overt action is theorised to be the development of a cognitive representation of the skill – a perceptual or conceptual model that is stored in memory (Scully & Newell, 1985). Neural imaging has shown similar brain activation during observations as during executions of motor tasks (Hodges et al., 2007; Vogt & Thomaschke, 2007). This has been suggested to indicate that motor programmes are accessed and activated during an observation of movement. Point-light observations of a skill can activate similar areas of the brain as do

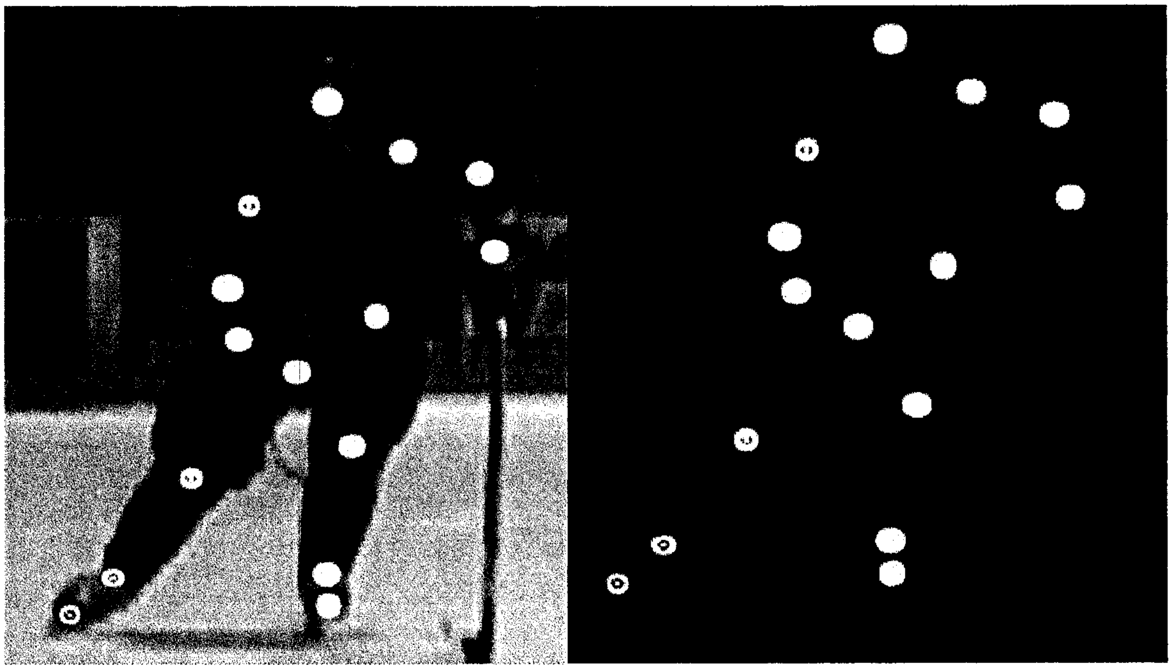


Figure 2.1 An athlete with joints marked by points of light (left) and a point-light model created from the same image (right).

observations of an ordinary video model of the same skill (Beauchamp et al., 2003). Even the learner's experience in performing a skill has an influence on the brain's activity when observing a movement. Calvo-Merino, Glaser, Grezes, Passingham, and Haggard (2005) reported that when a dancer observed the actions of other dancers, the observer's brain activity was different depending upon whether the dance being performed was from a domain or style in which the observer was a proficient dancer.

2.2.4 Perception and Processing of Visual Information

Perhaps the most persuasive evidence that learners create cognitive representations of motor skills through data reduction is the demonstrated ability of observers to perceive motion accurately when substantial data has been removed from the modelled action. From a point-light demonstration, a movement can be accurately identified by an observer. In a point-light demonstration a movement is represented by points of light that represent the joints involved (Figure 2.1). These demonstrations reduce a movement to the smallest amount of data possible, representing only a pattern of coordination (Scully, 1986; Scully & Newell, 1985).

Astoundingly, from observing a point-light demonstration of a particular performance, observers are able not only to identify the movement, but also to determine the model's gender (Barclay, Cutting, & Kozlowski, 1978; Cutting & Kozlowski, 1977; Kozlowski & Cutting, 1977), estimate the weight of an object carried by the model and the distance an object is thrown by the model (Runeson & Frykholm, 1981). From point-light models, observers can even distinguish their own or a friend's performance from others' performances (Beardsworth & Buckner, 1981). Scully and Newell found that in addition to recognising a dart-throwing action from a point-light demonstration, participants could *reproduce* the action. If such details can be discerned from this most limited of visual information, then this coordination pattern (including the way it changes in different circumstances) must be cognitively linked to the movement(s) from which it is derived. It is, therefore, logical to infer that one dissects the visual information of a movement and retains the data required to perceive and reproduce the movement in the future.

It is also important to recognise that point-light displays have been shown to have different effects than regular video presentations in facilitating learning in different populations. In children learning a bowling task, Hayes et al. (2007) reported that the group observing video models out-performed the group observing point-light models. Adults in that study, however, seemed to be able to perceive the point-light models as, or nearly as, effectively as they perceived video models. This suggests two things: (1) there is some information perceived from a video display that is not perceived from a point-light display, and (2) that adults are better able to process point light displays (as relative to their own ability to process video displays) than are children.

Since the brain is similarly active during the observation and execution of a motor skill (Beauchamp et al., 2007), it is not surprising that while performing a movement and simultaneously observing an opposing movement, the performance is interrupted. Bouquet, Gaurier, Shipley, and Blandin (2007) conducted an experiment to investigate the effect of observing a conflicting, or incongruent, movement to the one being performed. They found that, regardless of viewing a videotaped or a live human model, when participants moved an arm horizontally while watching the model move his arm vertically, the observer's motion was disrupted. This was also true when an observer's movement was vertical and the model's horizontal. When the model's action was congruent with the observer's (e.g. observer moving horizontally and model moving horizontally) there was no difference in the variation of the learner's movement from that congruent-model to a no-model (neutral) condition. This is yet further evidence of the link between the observation and execution of motor skills.

A second, similar experiment by Bouquet, et al. (2007) sought to investigate the impact of observing a representation (moving point of light) of biological or non-biological motion. The representation was created from the same model's movements as in the first study, and to create 'non-biological' motion, all variation in speed and amplitude of the movement was removed. The same effects were found for biological and non-biological motion for neutral, congruent and incongruent model conditions. As in the first experiment, a congruent model (biological or non-biological) showed no difference between neutral and congruent model conditions, and an incongruent model (either biological or non-biological motion) disrupted the observer's performance. Interestingly, the biological movement appeared to have some association with more variability of movement. The differences in variability approached but did not reach statistical significance ($p < 0.06$). This difference is logical, as the biological movement itself exemplified greater variability. So, while the effect of 'type of motion' cannot be accepted as true from these results, it is an intriguing finding. If further research finds a similar and significant result, it might indicate that the consistent, non-biological, motion provides a cleaner version of that most basic, visually obtainable information. This would be a further example of data reduction in observational learning. It is noteworthy as regards observational learning that this single point of light was interpreted as motion, and that it seemed to have the same effects on motion as the live or video model that it represented. Whether biological or non-biological, a single element of a dissimilar coordination pattern to the one being executed was enough to interfere with that executive function.

Observers unfamiliar with a given motor skill are, naturally, still able to assess whether or not they find the movement pleasing to watch. Spectators attend events like figure skating competitions, gymnastics meets, and dance performances as a form of recreation. Not all such spectators are skilled or experienced performers, or even knowledgeable observers of these movements, but still they attend. Paying spectators must find observation of these movements enjoyable, presumably because the movements are aesthetically pleasing. Scully (1986) examined the relationship between kinematic characteristics of a performance and the perception of aesthetic quality. Naïve observers did not give the same scores for a technically identical performance when it was presented once as an ordinary video and once as a point-light display, whereas experienced observers did produce the same scores in both cases. Technical marks were similar regardless of display condition. Experienced judges were less likely than naïve observers to give a particular performer similar scores for aesthetics and technical merit. It was still found, however, that high technical scores were related to high aesthetic scores, indicating that technically correct performances are aesthetically pleasing. There is, it seems, some link between technically good performance and positive aesthetic perceptions of performance. This, and the tendency of untrained observers to give similar technical and aesthetic scores, suggests that there is some basic perception about movement that is common to both. Since naïve observers' ratings of performances differ from those ratings given by experienced observers, some learning of how and what to observe during a performance must take place as an observer becomes experienced. Perception of either technical or aesthetic goodness is likely an adherence to the observer's cognitive representation of the movement; aesthetically good and technically good movements must each adhere to some common components of the representation, but not necessarily all. These results further support the existence of cognitive representations and also indicate that, in an individual, these representations develop and change over time.

Observers, especially skilled and experienced observers, are able to identify skills from cues occurring early in the movement pattern. This ability can also be taught. A non-athletic example would be a deaf person that learns to perceive both hand gestures and lip movements as having specific, linguistic meanings. In that same way, an athlete that is unskilled at recognising certain important movement patterns can be taught, through video demonstrations, to recognise them and anticipate their results. Burroughs (1984) found that baseball batters with film training were significantly more accurate in their abilities to predict pitch locations. Christina et al. (1990), in a single subject study, showed that an American-football lineman was trained to identify specific movements from early, visual cues. Their participant had good reaction time before intervention, but often reacted incorrectly by, for example, moving in the wrong direction. Through video training he learned to recognise certain coordination patterns visually, and was then able to identify and anticipate an imminent movement by an opponent. Salmela and Fiorito (1979) found that ice hockey goaltenders could accurately predict a shot's location before the puck left the shooter's stick. These findings are demonstrative of the ability of observers to learn to recognise specific movements from even a small amount of visual information. The observer must therefore perceive some information from motion and compare that information to a reference of some kind. This reference would be the observer's cognitive representation of the movement. For observers to improve in this ability to recognise a motor pattern from its earliest movements, their cognitive representations of those motor patterns must be improved. Since observers can improve and refine their abilities to recognise movement patterns, and can improve accuracy and consistency (Burroughs, 1984; Christina et al., 1990), they must also be able to improve and refine the cognitive models of those movement patterns, which are stored in their memories.

Even for observation it would appear that the cognitive model is as important, or perhaps more important, than the actual demonstration being observed. In several studies on racquet sports, by Abernethy (1988; 1989) and Abernethy and Russell (1987), even when certain body parts were artificially blocked from view, expert observers' eye movements when visually searching the video were the same as without this occlusion. These expert observers appear to base their search patterns on the skill model stored in his memory, rather than on the stimulus at hand. This makes sense, since it has been shown that brain activation is similar during the observation of and execution of the same skill (Beauchamp et al., 2003; Hodges et al., 2007; Vogt & Thomaschke, 2007), and this indicates that the cognitive model is being accessed in both cases. The learner recognises the skill early in the movement, (Burroughs, 1984; Christina et al., 1990; Salmela & Fiorito, 1979) presumably by accessing a cognitive representation stored in memory, and that from this representation executes what experience has taught him is the best search pattern. The cognitive representation appears to drive not only actions, but also observations. Therefore, the better an observer's cognitive representation of a skill, the more competent he will be at observing the movement. Skilled performance, then, would lead to skilled observation, and skilled performers may be better able than novice performers to utilise information that is presented in the context of a visual model.

2.3 *Combining Demonstration and Augmented Feedback*

Some research has been conducted examining combinations of augmented feedback with modelling or demonstration. When learners are exposed to a visual model of a skill to be acquired, their kinematic form has been shown to be more congruent with correct form than when learners do not view a demonstration of the skill (Magill, 1993; Magill & Schoenfelder-Zhodi, 1996; Wiese-Bjornstal & Weiss, 1992). For example, Magill (1993) found that participants given only verbal feedback on a gymnastic skill needed more KP about their actual body movements than did participants that had viewed a model. In a similar study, Magill and Schoenfelder-Zhodi (1996) found that those participants viewing a model required more information about a rope that was to be manipulated as part of the skill than about body movements. In both studies, it was found that both KP and modelling had significant effect upon learning the skill, but that there was no advantage in one above the other, or in combining visual modelling with KP. Neither group performed *better* than the other, but they did perform *differently* from one another. So, while quantitative differences in performance were not found, qualitative differences were. This indicates that, while some information may be common, learners do perceive different information from KP than they do from demonstrations, and vice versa.

Wiese-Bjornstal and Weiss (1992) investigated the combination of a visual model with auditory cues that direct the observer's attention. They found that the introduction of auditory cues seemed to cause a decline in performance quality immediately, but also that the greatest improvements in performance occurred after the introduction of cues. This suggests that it took some amount of time for the participants to be able to process the cues effectively alongside the observed model. Participants were girls aged 7 years to 8 years and 11 months, which may have had an impact on their cognitive ability to process information from both visual and aural sources simultaneously. Nonetheless, greater improvements in performance were associated with the introduction of cues to the visual demonstration, indicating that the participants became able to perceive, process, and utilise both sources of information. If, in tandem with a visual model, KP is presented visually, it may be more easily processed than verbal KP, as it does not require the learner to integrate information from both auditory and visual systems. The same may be true of implementing KP and visual modelling in concert over a longer period than in the studies by Magill, (1993) and Magill and Schoenfelder-Zhodi (1996). Those studies (Magill, 1993; Magill & Schoenfelder-Zhodi) occurred over a matter of days. A longer period of training may well yield different results.

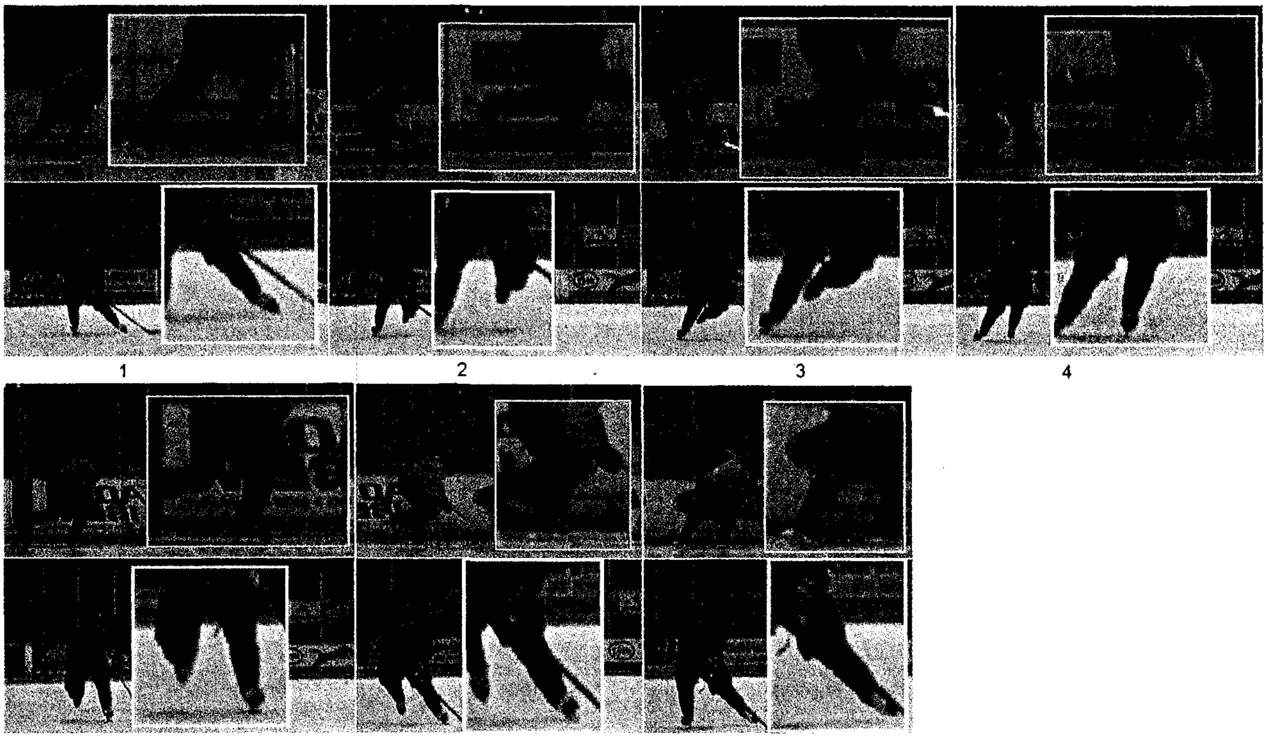
2.4 Kinematics of the Forward Skating Stride

The forward skating stride in ice hockey is a skill used to propel a skater down the ice. Though the actual speed at which a player skates during competition is dependent on many factors involved in a game, training for the forward skating stride is generally concerned with increasing a hockey player's maximal skating velocity. The specific term *forward* skating stride is important in the case of ice hockey, because the *backward* skating stride is a different, yet equally important, skill in that sport. The forward skating stride can be subdivided into two main phases. They are the power or thrust phase, during which the skater is exerting force to propel himself, and the recovery phase, during which the skater returns the propulsive leg under the body. One *stride* is the full execution of the power and recovery phases with *one* leg. The execution of power and recovery phases with both legs is generally termed one *cycle*.

The instants of *toe-off* and *heel-down* (Upjohn, Turcotte, Pearsall, & Loh, 2008) mark transitions between these two phases. Toe-off (Figure 2.2, pictures 1 & 7) is the instant at which the blade of the propulsive leg completely leaves contact with the ice surface. Heel-down (Figure 2.2, picture 3) is the instant at which the full skate blade (i.e. toe to heel) contacts the ice.

The recovery (Figure 2.2, pictures 1-4) phase begins at toe-off and terminates at heel-down. The purpose of the recovery phase is to return the propulsive leg from behind to underneath the body, where it can accept the skater's weight, and the opposite leg can commence its power phase. At toe-off, adduction of the thigh, and flexion of the hip, knee and ankle begin (Figure 2.2, pictures 1-2). As the leg is returned through the air, abduction of the thigh occurs (Figure 2.2, picture 3), to accommodate the subsequent power phase of the opposing leg (Hoshizaki, Kirchner, & Hall, 1989). Abduction of the thigh is followed by toe-down and then heel-down (Figure 2.2, picture 4), to accept the skater's weight.

The power phase (Figure 2.2, pictures 4-7) begins at heel-down and terminates at toe-off. At heel-down (as an approximation of the instant of weight acceptance) extension of the hip,



1 2 3 4 5 6 7

Figure 2.2 Image sequence of the forward skating stride in frontal (top) and sagittal (bottom) planes.

knee and ankle (plantarflexion) begin, and continue through toe-off. At toe-off, the power phase terminates.

Throughout the stride, the skater's centre of mass experiences essentially no vertical displacement (Haché, 2002). Because of this, the centre of mass must displace mediolaterally, meaning that the skater shifts his weight from side to side, to allow the recovery phase to occur. If this weight shift does not occur, the skater would be unable to lift his leg and return it under his body. Therefore at toe-off of the power-leg, the participant will have shifted his weight entirely to the supporting (flexed) leg. This enables the recovery of the power (fully extended) leg, and allows the supporting leg to begin the power phase, as it can now move the centre of mass forward by exerting force behind the skater.

The training goal of the forward skating stride is maximal forward velocity, and the two prime factors in achieving that goal are stride length and stride rate. Stride length is the displacement from maximal knee extension in one stride to the same event in the subsequent stride (Marino, 1977) and stride rate is the number of strides taken per unit of time (e.g. strides/second). That is to say, the longer each stride is, and the more strides are executed in a period of time, the faster will the skater propel himself.

Marino (1975; 1977) found that stride rate is a more significant factor in velocity than is stride length. However, in a later study Marino (1984) reported that when stride rate was constant, stride length was significantly, positively related to velocity. Marino (1975) and Hoshizaki et al. (1989) found that time of thrust shortens as velocity increases. This means that, at higher velocities, less time is spent generating thrust. Therefore skaters should be encouraged to pursue high stride rates without compromising the technical execution of a long and powerful stride (Marino & Drouin, 2000).

Increasing either or both of the length of the stride, and the rate of striding will increase velocity. Coaches target specific, mechanical elements of the forward stride to increase both stride length and stride rate. Increasing the stride rate can be achieved by reducing the temporal duration of each stride. This is to be achieved through faster extensions of the hip, knee and ankle during the power phase and their flexions during the recovery phase. This can be of particular benefit when reducing the time of the recovery phase of the stride. As soon as the power phase terminates, commencing the recovery phase, the skater is no longer applying force to the ice, and so begins to decelerate due to friction (Marino, 1975; 1977). The durations of time spent in both phases of the skating stride are negatively related to velocity (Pagé, 1975). Reducing the time of recovery reduces the period of deceleration, thereby minimising the loss of velocity. For this reason, rate of recovery is an important component of the forward stride.

Increasing the impulse of the exerted force, and ensuring that its direction is optimal will result in greater stride length. The optimal angle of the blade is not precisely identified in the literature. Theoretically, a blade angle perpendicular to the desired direction of travel will generate the greatest propulsive force; however such an angle would prevent the skate blade from gliding forward in the desired direction of travel, therefore forcing greater deceleration during thrust. An angle that allows as much force as possible directly behind the skater, while still allowing glide at the skater's instantaneous velocity is optimal. Increasing the time over which a force is exerted increases the impulse, though this would reduce stride rate. An optimal balance between maximising impulse and maximising stride rate must be found by a skater. Generating greater force will increase the impulse, and high-level skaters have shown the ability to produce greater force than lower level skaters (McPherson, Montelpare, Wrigley, & Purves, 2004; Upjohn et al., 2008). With observational learning, however, kinematic characteristics are directly perceived and kinetic characteristics are not. Extension of the hip, knee and ankle through the greatest possible range of motion, while still exerting a large force, will increase the impulse. Initial flexions and final extensions of these joints determine that range.

Marino and Drouin (2000), Hoshizaki et al. (1989), and McCaw and Hoshizaki (1987) agree that initial knee flexion is more crucial to velocity than is final knee extension. Initial knee flexion is the angle of the knee of the support leg at maximal extension of the knee of the thrusting leg, while final knee extension is the angle of the knee at full extension of the thrusting leg. While past researchers have observed that initial knee flexion seems related to higher calibre performance on this skill, regression studies (e.g. McPherson et al., 2004) have not established a relationship between initial knee flexion and higher velocity. However, greater initial knee flexion leads to a lower overall body position. A lower overall body position leads to a lower position of the centre of mass, and to a lower angle of the orientation of the thrusting leg (Figure 2.2, picture 7). Both the height of the centre of mass (McPherson et al., 2004) and the angle of orientation of the thrusting leg (Pagé, 1975) are inversely related to skating velocity. A lower angle of orientation of the leg allows longer strides, as well as a larger horizontal component of the force applied by the leg. Hoshizaki et al. called greater initial knee flexion a *predictor of skilled performance*. When skating *lower*, a player gains greater stability. A lower stance brings the centre of mass closer to the base of support, and greater joint flexion allows the skater to control his equilibrium with isometric contractions. If upright, the skater would have to rely more on skeletal support than muscular support. With more muscular support, the skater has more control over the forces that maintain equilibrium, allowing him to compensate quickly if his equilibrium is disrupted. The ability to maintain equilibrium in an open competitive environment is a necessary ability for a hockey player, and is a means to maintaining skating speed in difficult circumstances. Initial knee flexion can be connected logically with other variables that are related to velocity, and accommodate bodily control and stability.

Other important factors contributing to skating velocity are related to maximizing the amount of horizontal component of the thrusting force. As the angle between the thrusting leg and the ice decreases, the horizontal component of the thrusting force increases. Hoshizaki et al. (1989) demonstrated that the force exerted between heel-off and toe-off is more effective than the forces exerted during other portions of the stride, which can be attributed to the lean of the striding leg being greater during this portion of the stride. Greater knee flexion of the support leg (initial knee flexion) (Hoshizaki et al.; Marino, 1975; McCaw & Hoshizaki, 1987; Pagé, 1975) and the placement of the foot at toe-down (Marino & Drouin, 2000) are important indicators of ability, facilitating a lower, absolute angle of the propulsive leg throughout the power phase. This lower angle is positively related to velocity (Pagé). Marino (1984) recorded that younger children skate in a more upright position than older children; younger children were also seen to skate at lower velocities than older children. This difference in velocity by age was attributed to stride length, as stride rate did not vary significantly across the age categories involved in the study (Marino, 1984). McPherson et al. confirmed the early finding by Marino (1975) that lower toe to hip distance at touchdown is a predictor of velocity; the lower distance would be achieved through the initial knee flexion that has been shown to be a predictor of ability (Hoshizaki, et al.; Marino, 1975; McCaw & Hoshizaki; Pagé), and aligns with the importance that has been attached to the placement of the foot (Marino & Drouin). The relationship between stride length and height of skating stance (lower stance achieved by greater joint flexion) is easily explained: as the vertical magnitude of the leg is reduced, when the leg is extended its horizontal magnitude will be increased, since the absolute length of the leg is constant. These collective observations support Marino (1975), Marino and Drouin, and McCaw and Hoshizaki's emphases on the importance of joint flexion: the greater the flexion at the beginning of this portion of the stride, the greater the range of motion through which this force will be exerted, increasing impulse and hence, resultant velocity.

2.5 Dartfish Software

Dartfish Ltd. manufactures and sells a range of commercially available software programmes with powerful tools that can incorporate feedback into a video of a motor performance. The software is primarily marketed to coaches, but is also designed for other applications related to teaching and movement rehabilitation. There are six versions with different features and capabilities. In this study, Dartfish ProSuite v. 4.0.9.0 was used. Dartfish software allows visual KP to be added to video, in an instructional context, immediately following a performance. The software's tools include measurements of angles, distances and time, as well as various methods of highlighting or marking certain locations or events. This gives the user the ability to control what information is presented to the observer. Hodges et al. (2007) specifically indicate that Dartfish software "provides practitioners with a viable method to manipulate access to relevant...information in the field setting" (p. 542). The product is already in widespread use with athletes at all levels in many sports (Bartoli et al., 2004; Baudry et al., 2006; Demeris, et al., 2002; Hars & Calmels, 2007; Hayes, Hodges, Scott et al., 2007; Hodges & Williams, 2007; Kokaram, et al., 2006; Sheppard, 2006; Thomas & Stratton, 2006; Williams & Hodges 2005) and in multiple other applications (Abercrombie et al., 2006; Miller & Kang, 2007; Petersen et al., 2007; van Vuuren-Cassar & Lamprianou, 2006; Womersley & May, 2006).

Dartfish software allows users to import video of human movement for analysis and to provide feedback to an athlete (or other subject). Video can be imported into the programme either directly from a camcorder or VCR, or in several common, video file formats. Once imported, video files can be split, trimmed, duplicated and converted to different formats to accommodate the user's needs. Qualitative and quantitative tools are available to the user to analyse movement and provide visual augmentations to video feedback. These can be displayed within the Dartfish application, or exported to removable media or email so that they can be distributed for viewing on any computer. Exporting tools are meant to distribute an analysis for later viewing, which allows a coach to extend the learning process beyond a scheduled practice session. Within the Dartfish application, analyses can be saved for later viewing or viewed immediately. This allows a coach to provide visually augmented video feedback immediately following performance, through use of Dartfish's *InTheAction* module.

Using the *InTheAction* module, Dartfish has the capability to capture video directly to a computer hard drive, within the application, making it available for immediate analysis. Specific feedback on a trial can then be given to an athlete immediately following that trial. This requires a mobile or on-site computer connected to a MiniDV camcorder, via an IEEE1394 (a.k.a. *FireWire* or *iLink*) connection. Hard drive and Mini DVD camcorders cannot be used with *InTheAction*. Once set up, normally with the camcorder on a tripod, the user can see the camera's view on-screen, and press *Record* and *Stop* buttons on the infrared remote control, on-screen with the mouse, or with pre-set (by the user) shortcut keys on the keyboard, to control when hard drive video capture starts and ends. Within the module, all analysis tools except video overlay are accessible to the user. The *InTheAction* module is designed to allow the user to generate and provide immediate, on-site feedback to the athlete that is not available with traditional coaching, or even with traditional video editing programmes, especially when it comes to quantitative measures.

Figure 2.3 Freehand and preset drawing tools.

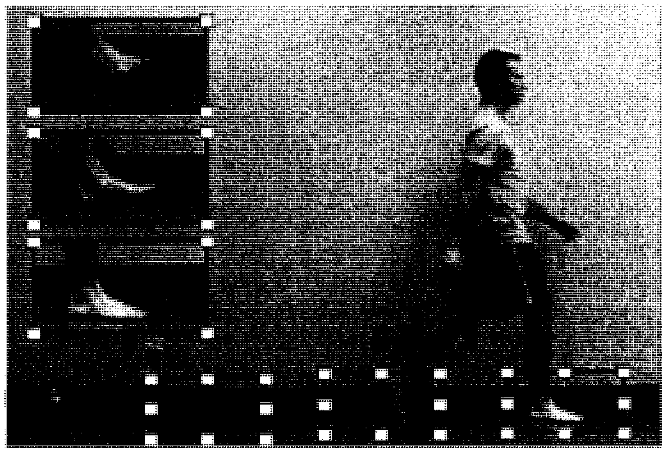


Figure 2.4 Clone rectangles.

The software's qualitative tools are primarily designed to draw the observer's attention to specific locations or events on the screen during playback. These include highlighting, free-hand drawing, and drawing of pre-set shapes (Figure 2.3). Some more complex tools include clone rectangles, video overlay, and split-screen capabilities. Clone rectangles provide a zoomed-in view of a particular area of the regular video. Inside the clone-rectangle, the video plays simultaneously with the main image, but is enlarged. The user can freeze the clone-rectangle's playback at any time, so that the main video proceeds but the clone-rectangle pauses playback on a particular field of video (Figure 2.4). The video overlay and split-screen features allow an observer to compare two different videos simultaneously. Video-overlay lets a user place a partially transparent version of *Video A* over an opaque *Video B* so that the observer can note differences between the two videos. The split-screens feature allows the user to place up to five video clips on the same screen, side by side, playing them simultaneously, also allowing the observer to make visual comparisons across the videos. These can be used to allow comparison between two athletes, or different performances by the same athlete. A coach might wish to compare two athletes on a team, compare an athlete under his instruction with an elite athlete or a competitor, or compare an athlete's good performance with a poorer performance. These allow

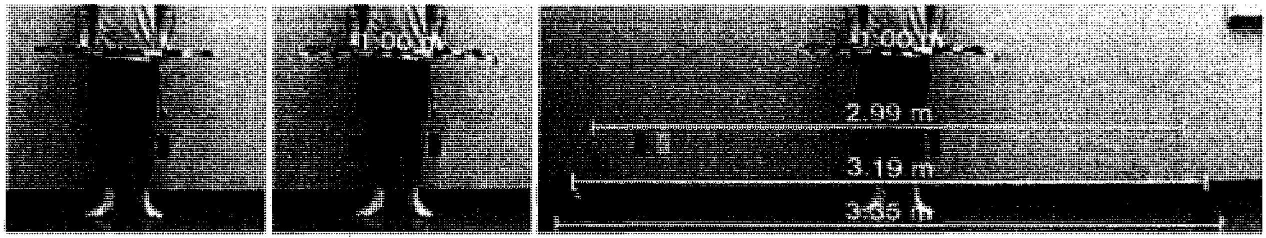


Figure 2.5 Calibration and distance measurements

the coach and/or athlete to illustrate differences in performance associated with differences in results.

Quantitative tools included in Dartfish are measurements of angles, distance/displacement, and time. For distance measurements, a reference object of known length is required, such as a metre stick (Figure 2.5, left). Selecting the *Distance* tool, the user will use the mouse to draw a line from one edge of the reference object to the opposite edge, and then identify that this line is a reference measure of length *x* (Figure 2.5, middle). Distance measurements can be made in metric or Imperial units; this is selected by the user in the programme's options. To measure distances or displacements after setting the reference, the user simply selects the distance tool and draws a line in the same way as for the reference between the two desired points (Figure 2.5, right). To measure angles the user selects the *Angle* tool, clicks on the vertex of the angle to be measured and, holding the mouse button, draws a line to second point of the angle, releases the mouse button, moves the mouse cursor to the third point of the angle, then clicks the mouse button again (Figure 2.6). For both distance and angular measurements, each vertex or end point can be easily moved with the mouse until the user is satisfied with the accuracy of the position. Measures of time are done with the *Stopwatch* tool. The user selects this tool, and locates a stopwatch image (Figure 2.7) in any desired location on the video. This stopwatch is precise to one one-hundredth of a second (two decimal places). The on-screen appearance of measurements of angles, distances and time (e.g. line-thickness, colour, text-size) can be changed to the user's liking.

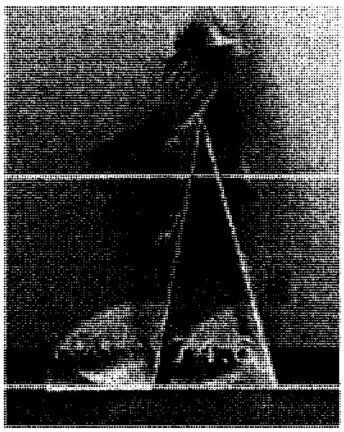


Figure 2.6 Angular measurements.

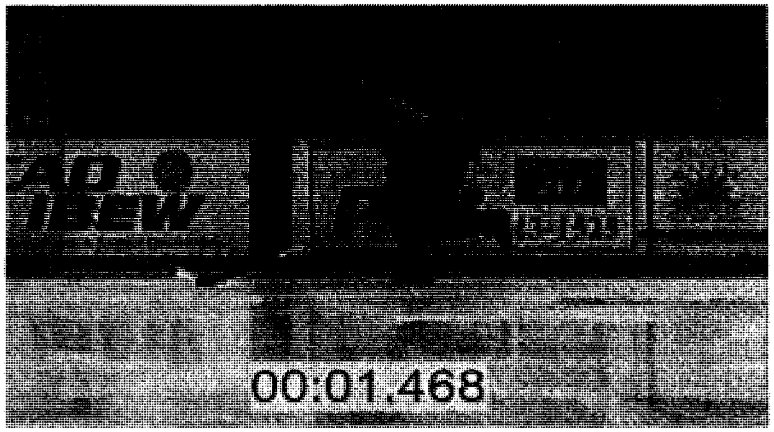


Figure 2.7 Stopwatch tool.

A search of the relevant literature returned only one published study examining the effectiveness of Dartfish in affecting change in motor skill performance: Baudry et al. (2006) studied the combination of self and expert modelling on performance of the pommel horse circle in gymnastics. One group of intermediate gymnasts received both the modelling, and their regular coaching, while the control group received just their regular coaching. Training was done over five days. The feedback consisted of a split-screen video, with video of an expert performer on one side and video of the participant's most recent trial on the other. The participant's body-alignment was then measured, and a coach explained how the participant's body alignment differed from the expert's. A pre-test (measuring body alignment) was followed by the five days of training, and then a post test. On the post test, the experimental group's performance was significantly better than on the pre-test. The control group showed no change from pre-test to post-test. A retention test after another five days, during which all participants went back to regular training without video, showed the same result as the post-test. On both post-test and retention-test, the Dartfish group showed more improvement than the control group.

2.6 *Summary*

Advances in video and computer technology that are making products like Dartfish more accessible and user-friendly have the potential to push sport coaching at all levels into a new, technologically-based paradigm. Such tools are already widely used for many athletic, clinical and academic purposes (e.g. Bartoli, et al., 2004; Baudry et al., 2006). That alone may be impetus enough to test Dartfish (Salo & Grimshaw, 1998). In the theoretical basis heretofore discussed, new investigations are not only a matter of validating a popular tool, but also a crucial step in expanding observational learning theory, feedback theories, and the horizons of applied biomechanics.

Results from brain imaging studies indicate that some basic information about biological motion is stored, and neural activity shows that this information is accessed during both observation and execution of motion (Beauchamp et al., 2003; Hodges et al., 2007; Vogt & Thomaschke, 2007). Past research (Burroughs, 1984; Christina et al., 1990; Salmela & Fiorito, 1979) has also clearly demonstrated the presence of a process by which improvement and refinement of the observer's perceptual model of a movement occurs. If that same perceptual model is called upon when executing the movement, then this process will also continue to improve and refine the observer's performance of that skill, and data from performance experience will also be integrated into the model. KP has been shown to lead to changes in performance (Kernodle & Carlton, 1992; Magill, 1993; Magill & Schoenfelder-Zhodi, 1996), and so information from KP must also be integrated into the cognitive representation.

A unified presentation of KP and self-observation (using a video demonstration) may have immense benefit. Presenting KP within a video demonstration may allow more efficient organisation and application of the information a learner derives from the feedback. This would be especially true for experienced and expert performers whose more refined cognitive models of motor skills can allow them to perceive and utilise more precise, and perhaps complicated, information.

3 PURPOSE

The purpose of this study was to determine if the delivery of knowledge of performance through the use of Dartfish video software resulted in a targeted change in performance on a specific, kinematic variable during forward skating.

4 METHODS

4.1 Pilot Investigation: Reliability and Validity Testing

A pilot study was conducted to test the validity and reliability of angular measurements made using Dartfish software. This included three experiments. The first compared angular measurements made with Dartfish to angles calculated from surveyed positions of stationary objects. The second compared measurements of the relative knee angle of a runner on a treadmill made with Dartfish software to those of the same angle, in the same video, made with Vicon Motus software. The third experiment tested intra-rater reliability of Dartfish measurements of the relative knee angle of hockey players, outfitted in full equipment. In the third experiment, measurements of the same video were made by the same rater on different days, and the differences in these measurements were assessed. Bland and Altman 95% limits of agreement were used to assess agreement between the two sets of measures in each of the three experiments. In the second experiment, an intraclass correlation coefficient was also used.

Validity and reliability were established in the pilot study. When measuring angles between stationary points, the range of error was found to be -1.81° to 1.92°, 95% of the time, as compared to the true measurement. Measuring angles from marked, moving objects (segmental end points) the range of error was found to be -4.15° to 5.19°, 95% of the time. Comparing measurements taken from the identical video on different days, the range of error from day 1 to day 2 measurements was found to be -4.8° to 5.46°, 95% of the time. Some calibration issues may have reduced the accuracy of the Vicon Motus measurements; it must also be recognised that Vicon Motus measurements were neither smoothed nor filtered, and were indirect measurements inclusive of some error of their own. This might have affected the Dartfish to Vicon comparison. The reliability analysis was expected to show a wider range of error than the validity analyses, as hockey players' equipment obstructed a clear view of participants' bodies, making it difficult to identify segmental end points with precision. The ranges of error found by the pilot investigation were similar to what was speculated to be found prior to the analyses, though with no precedent these speculations were based solely on anecdotal experience. Dartfish was not expected to approach the levels of precision and accuracy of Vicon Motus, as the needs of the applied, instructional setting are not as stringent as the needs of purely kinematic research. Full results and discussion can be found in Appendix B.

4.2 Participants

Participants in this study were four volunteers from the Lakehead University varsity men's ice hockey team. They were recruited with the assistance and cooperation of the team's head coach. The Lakehead team was consistently rated in the top ten men's hockey teams in Canadian Interuniversity Sport (C.I.S, formerly C.I.A.U.) throughout the 2007-2008 season and finished the regular season atop their division. All four participants had experience playing Major Junior A hockey (i.e. Canadian Hockey League, a.k.a. CHL) prior to playing on the Lakehead team. Players ranged in age from 22 to 24 years, making them Senior athletes in their sport (Canadian Hockey Association, 2007). Based on age, and a high level of competitive experience, all participants were considered to be high-performance, adult hockey players.

Table 4.1 Participants' demographic data, including experience above minor hockey.

Participant	Age	Height	Mass	Years in CIS	Years in CHL
1	24 years	183 cm	86 kg	3	4
2	23 years	188 cm	82 kg	2	4
3	22 years	185 cm	101 kg	1	3
4	21 years	178 cm	87 kg	1	4
Means:	**22 years**	**182.75 cm**	**88.25 kg**	**1.75**	**3.75**

(Some data acquired from the Internet Hockey Database (Slate, 2008)).

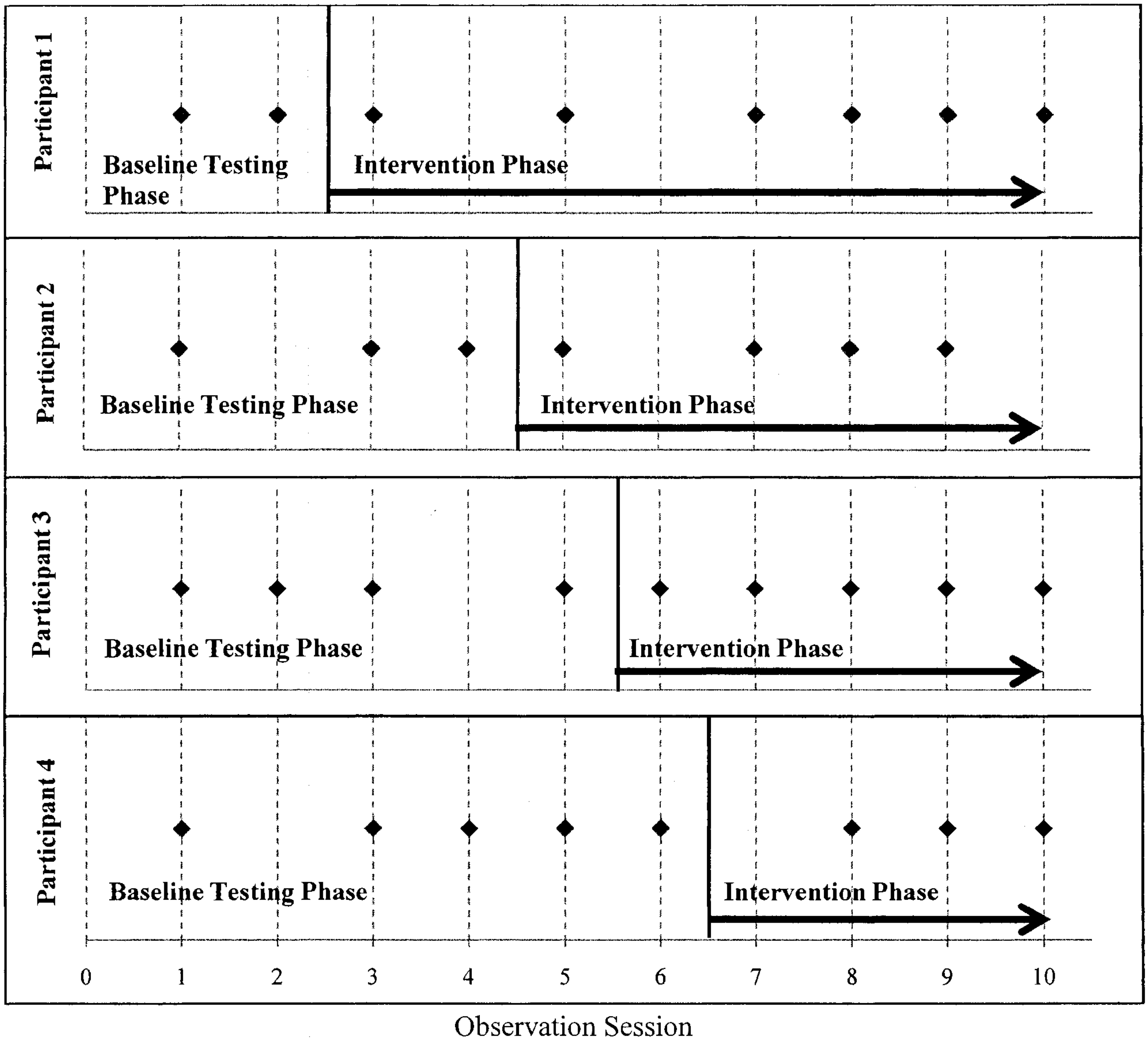


Figure 4.1 Participant condition & observation by session.

4.3 Research Design

A single-subject, multiple-baseline, across-participants, AB design was used. This consisted of two phases: (A) base-line testing followed by (B) intervention with visually augmented video feedback. With multiple baselines, each participant served as his own control, with his baseline-phase data compared to his intervention-phase data. The commencement of the intervention phase was staggered, so that participants began the intervention phase on different days. Their progress from baseline to intervention is illustrated in Figure 4.1, where each data point represents an observation session, and the vertical line divides the baseline testing phase (left) from the intervention phase (right). A data point appears on a participant's graph for each observation session he attended; if there is no data point, this indicates the participant was absent. This is similar to the design used by Ram and McCullagh (2003) who investigated the effects of self-modelling on the overhand volleyball serve in five intermediate participants. Their intervention, like the present one, involved video of the participants as feedback, though without augmentation. This method of staggering the commencement of intervention is designed to reduce threats to internal validity. If changes from the baseline are consistently seen at the beginning of intervention, then "the effects can be attributed to the intervention rather than to extraneous events" (Kazdin, 1982, p. 126).

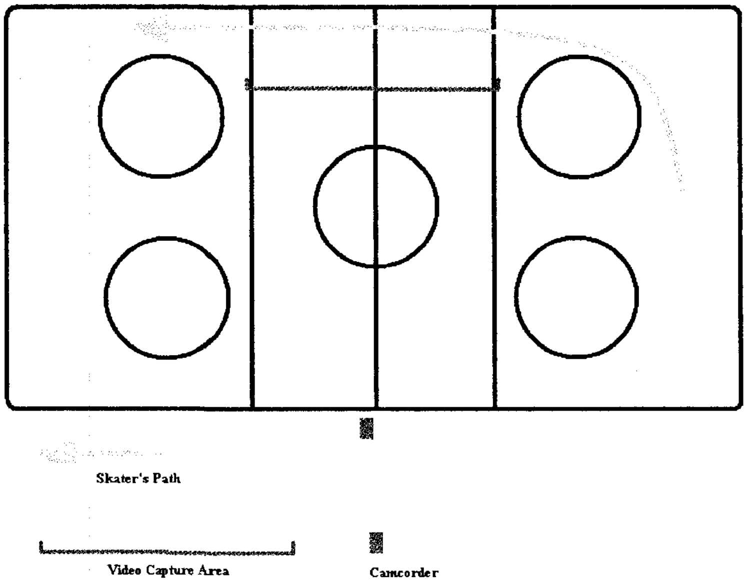


Figure 4.2 A diagram of the data collection site.

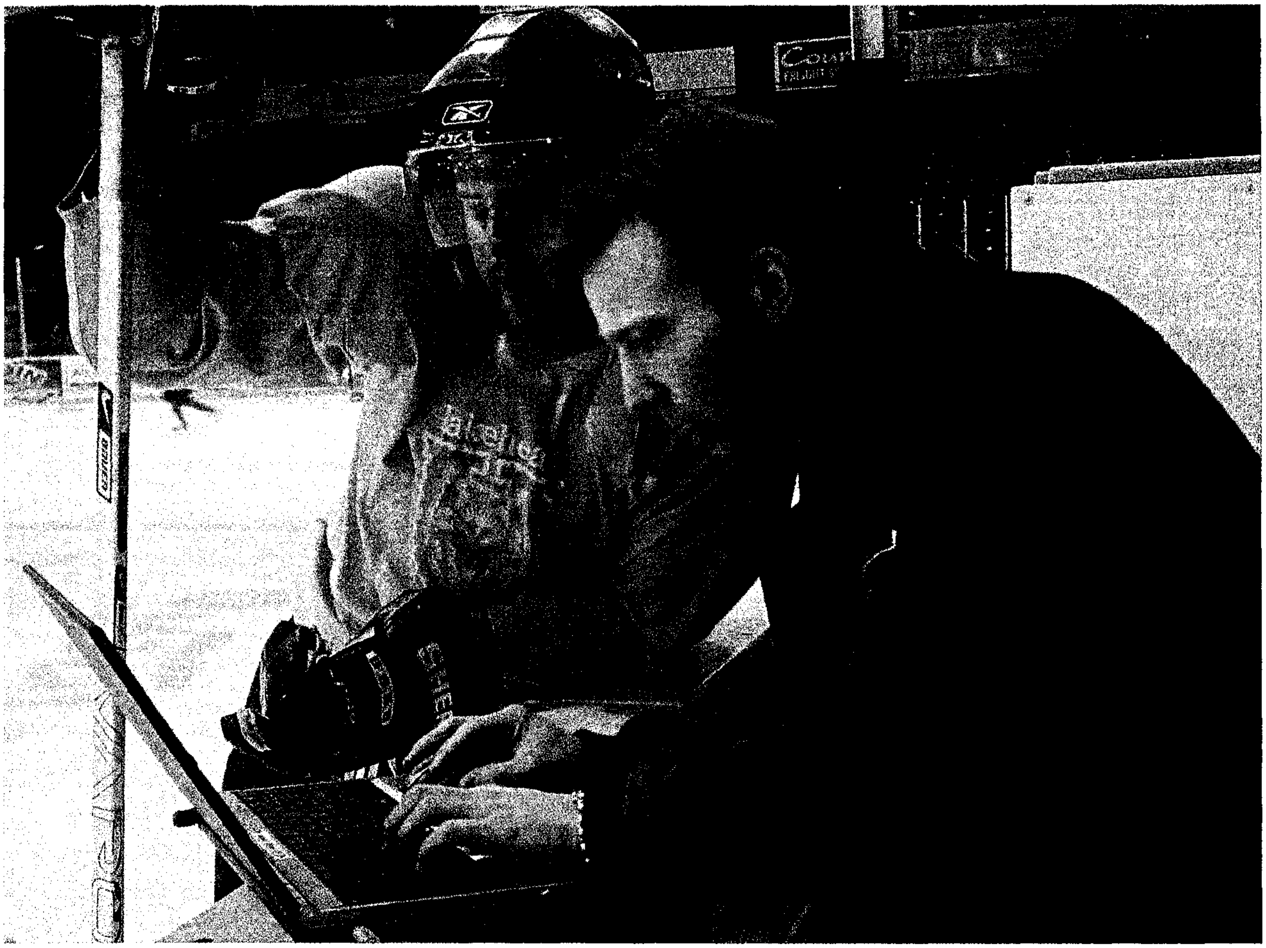


Figure 4.3 A participant reviewing KP for his previous trial.

4.4 Procedures

The study was comprised of 10 observation sessions, with each participant attending as many sessions as he was able. Participants 1 and 4 completed eight sessions, participant 2 completed seven sessions, and participant 3 completed nine sessions. During each session, (in either phase) each participant performed 10 trials of skating, at his maximum velocity, through a prescribed course (Figure 4.2). A Panasonic PV-GS300 Mini-DV camcorder captured these trials to Mini-DV cassettes and/or directly to a computer hard-disc.

During base-line testing sessions each participant completed the 10 trials, receiving no information regarding his performance. These 10 trials were recorded on Mini-DV tape.

Angular displacements for specific joints, at the critical instant of maximal extension of the knee of the thrusting leg, were measured using Dartfish.

The introduction of the intervention was staggered; this means that each participant began the intervention on a different session (Figure 4.1). The staggered introductions were based on the number of baseline sessions completed by a participant, rather than on an absolute, chronological schedule. For any participant, intervention did not begin until sufficiently stable base-line data from that participant, on the measurement of interest, had been obtained. When more than one participant met this criterion after the same number of baseline observations, one of those participants was selected randomly.

Procedures for the delivery of the intervention were adapted from those used by Baudry et al. (2006). During intervention, participants performed 10 trials in the same manner and on half of those 10 trials data were analysed immediately. This analysis was used to deliver feedback to the participant, using Dartfish software (Figures 4.3 & 4.5). The camcorder simultaneously captured data to Mini-DV cassette, and directly to a personal computer (Sony Vaio VGN-SZ120P) hard-disc through a *firewire* (IEEE1394) cable. On the first, third, fifth, seventh and ninth trials of a session, the participant received immediate feedback from the data captured to hard-disc. The feedback was given on a single variable and on the same variable every time. The criteria for selecting that variable for each participant were: (1) sufficient stability of base-line measures, (2) importance of the angle to the skill, and (3) identifying a difference between baseline performances and optimal performance, as defined by the skill expert (see Section 4.5.2).

Previous researchers have suggested methods and mechanisms by which added, visual information can be made useful to an observer. Slow-motion replays and multiple repetitions of replays (based on suggestions made by Williams (1989) and Gould and Roberts (1982) respectively) were made available to participants. It has also been suggested that superimposing point-light displays on corresponding video presentations could be more effective than either point-light or video displays alone (Hayes, Hodges, Scott et al., 2007). In this study, angular measurements were displayed by superimposing lines onto the video. These lines had vertices and end-points in positions that would have been marked in a point-light display of the skill.

For Participant 1, the procedures used to deliver KP during his first intervention session differed from the other sessions. The feedback delivered during the first intervention session focused on the orientation of the thrusting leg (Figure 4.4), and feedback incorporated superimposed measurements highlighting the orientation, compared to the horizontal, along with verbal indication of the direction of a desired change. (e.g. "Your leg should lean farther forward.) The participant found this difficult to understand and it was also determined that this orientation essentially combined the variables of both hip extension and knee extension, making it imprecise. Beginning with Participant 1's second intervention session, the procedures were

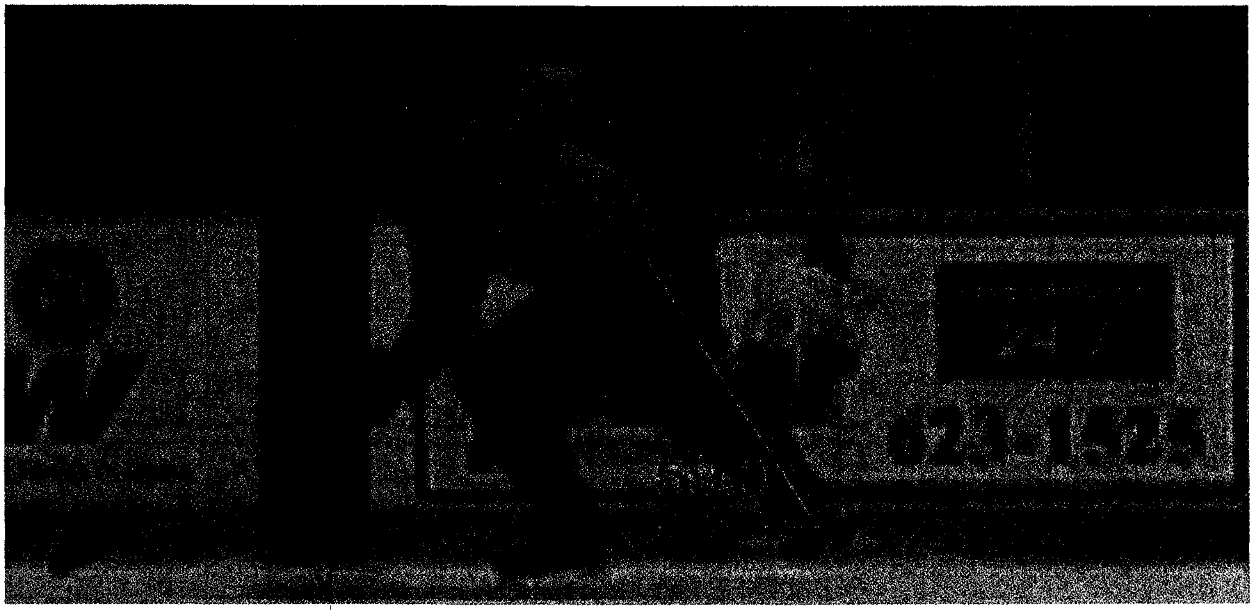


Figure 4.4 Original KP for Participant 1.

4.5 Variables

4.5.1 Independent Variable

The independent variable was the introduction of the Dartfish intervention. Dependent scores from before and after the introduction of intervention were compared. If a training effect due to the intervention exists, it should be related to the introduction of intervention, regardless of when the intervention began.

4.5.2 Identification of the Skill Expert

For the purpose of identifying dependent variables, and optimal scores, a hockey skill expert was required. The head coach of the Lakehead University men's hockey team, Don McKee, was identified and volunteered to assist in this role. Mr. McKee had 25 years of experience coaching Major-Junior A, C.I.S., and professional hockey (Slate, 2008), held a master's degree in physical education, was certified at Level IV in the National Coaching Certification Programme, and was an instructor in the Hockey Canada Coaching Programme (University Hockey Development Inc., 2007).

4.5.3 Dependent Variables

The purpose of this study was to identify changes in the performance of the forward skating stride. In training with tools like Dartfish software, a goal of training is to affect targeted changes in an athlete's form. As described in Section 4.3, one aspect in the form of each participant's performance was selected as a target for a specified change; this was a relative, or absolute, angle measured in degrees. The selected angle for each participant was the primary, dependent variable. Other angles were secondary, dependent variables. The following angles, illustrated in Figure 4.6, were selected by the researcher, in consultation with the thesis advisory committee, and the skill expert:

1. *Final knee extension*: The maximal extension of the knee of the thrusting leg.

2. *Initial Knee Flexion*: the angle of the knee of the supporting leg at maximal knee extension of the thrusting leg.

3. *Trunk Lean*: The interior angle between the torso (line from hip to base of neck) and the x-axis (horizontal line passing through the hip) at maximal knee extension of the thrusting leg.

4. *Hip Extension:* The angle between the thigh (from hip to knee) and the y-axis (vertical line passing through the hip) at maximal extension of the thrusting leg.

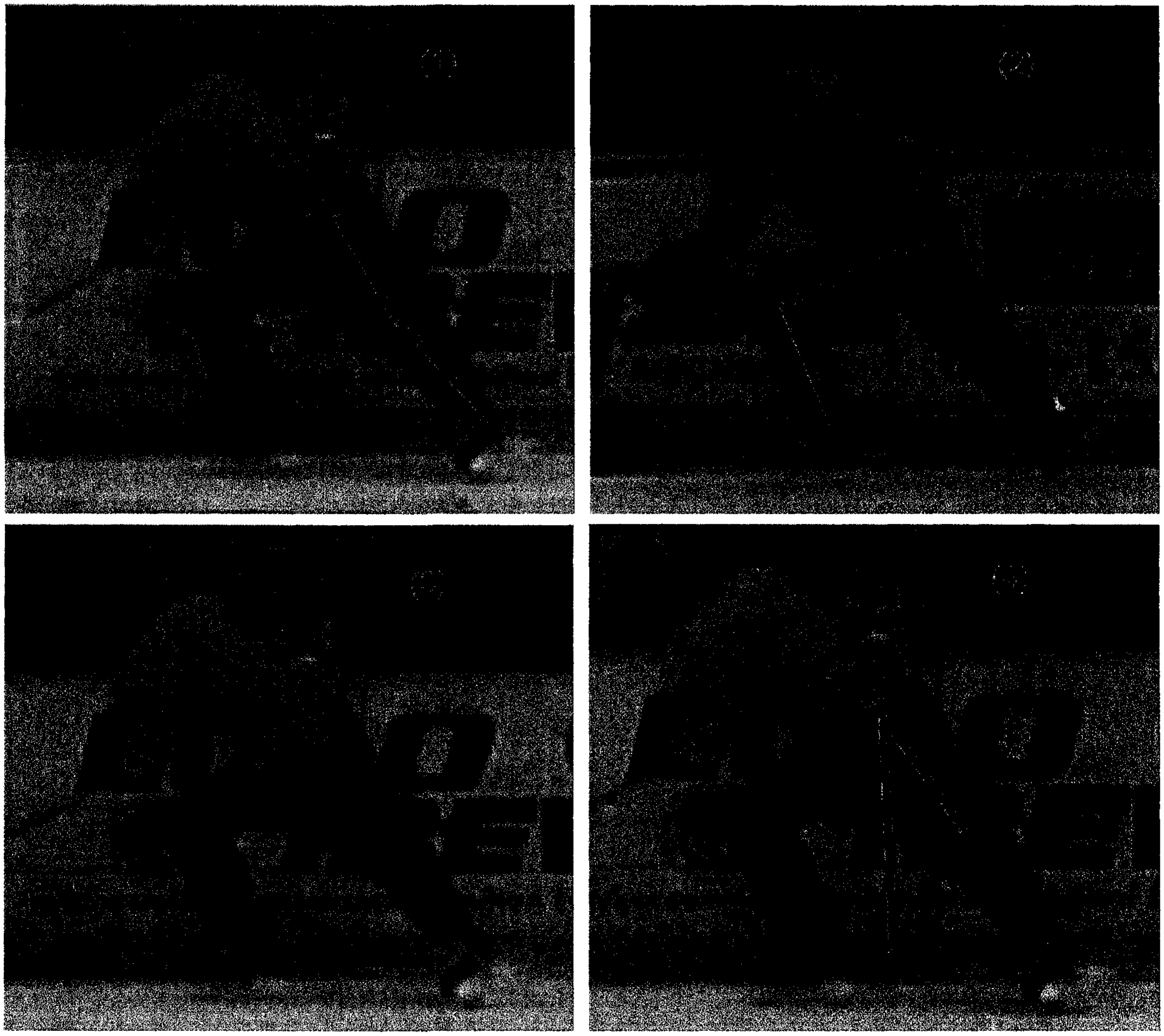


Figure 4.6 Dependent Variables: (1) final knee extension, (2) initial knee flexion, (3) torso lean, and (4) hip extension.

4.6 Analysis of Data

The results of this study were analysed to assess changes in mean, level, variability and trend following the introduction of the intervention. Each participant's data were treated individually; participants' data were not combined. Visual analyses were used to assess changes in mean, level, variability and trend, and rate of change, in each dependent variable. Visually observed differences in means between the baseline and intervention phase data were confirmed using the student's t-test, calculated with SPSS 16.0 (SPSS for Windows, Rel. 16.0.1. 2007. Chicago: SPSS Inc.). Trend lines were generated with Microsoft Excel (Microsoft® Office Excel® 2007 (12.0.4518.1014).

A two-group, independent samples t-test was selected, using the unstandardised, unpooled variance term for the denominator. The number of observations before and during intervention was sufficient for a parametric test, given that the t-test for independent group comparison is so robust. Since this is a single-subject comparison, within-group variance does not exist. The test was used to compare mean pre-test (baseline) values to mean post test (intervention) values.

Visual analysis consisted of graphing each variable across time, and visually comparing the characteristics of the data during baseline testing and during intervention for each variable and for each participant. Visually identifiable changes in the level, variability and trend were noted for each participant and across participants. Considerations used in the visual analysis included: (1) assessment of stability of the baseline data, (2) whether a change was observed after intervention, and how long after intervention it occurred, (3) the size of any observed change and (4) whether any change was observed in multiple participants.

5 RESULTS

The results are presented by each criterion for visual analysis: mean, level, variability, trend, and latency of change. Each participant's data have been analysed independently. The critical consideration is whether changes are temporally related to the introduction of intervention. The results are presented under the following headings: (1) Selection of the Targeted Variable, (2) Changes in Level, (3) Changes in Mean, (4) Changes in Variability, (5) Changes in Trend and (6) Latency of Change, and (7) Results of the Questionnaire.

5.1 Selection of the Targeted Variable

As described in section 4.4, one of the four, dependent variables was selected for each participant as the target of the intervention (Table 5.1). The dependent variable final knee extension was first identified as a target for change by the skill expert. For each participant, baseline-phase scores for this variable were considered suitably stable to be used as a control for intervention-phase scores. However, for all four participants, it was decided that these scores were simply too close to the optimal score of 180°. The participants wore full hockey equipment, which was bulky and limiting to flexibility and range of motion. It was not clear what the maximum, possible leg extension would be for each participant. Even though 180° was deemed to be the optimal angle of final knee extension, it could have been the case that the

Table 5.1 Intervention information by participant

Participant	Baseline Testing Sessions	Intervention Sessions	Targeted variable for intervention
1	3	5	Initial Knee Flexion
2	3	4	Initial Knee Flexion
3	4	5	Initial Knee Flexion
4	5	3	Initial Knee Flexion

maximum possible extension was less than that. With this in mind, final knee extension was excluded as a targeted variable. The targeted change was decrease in this angle.

The second dependent variable initially identified for intervention was initial knee flexion. It was determined, for participants 1, 2 and 3, that suitably stable baseline scores had been observed for this variable throughout baseline testing. For participants 1, 2, and 3, it was then determined that baseline testing scores for knee flexion were sufficiently different from the optimal score of 90° for a change to be observed. For participants 1, 2, and 3, initial knee flexion was therefore selected as the target variable for intervention. For participant 4, scores continued to exhibit wide variability throughout five baseline testing sessions, encompassing 50 observations. With 50 observations available for the assessment of stability, Participant 4's performance was deemed to be erratic and inconsistent. Inconsistency is an undesirable trait in athletic performance because it introduces uncertainty into competitive situations; the coach may not know what to expect from the athlete on a given day. For Participant 4, a decrease in either (or both) of level and variability of scores for initial knee flexion would be considered an improvement in performance. This means that an improvement in performance would be indicated by one or both of: (1) a change from higher angles of initial knee flexion to lower angles of initial knee flexion and (2) a change from inconsistent scores to consistent scores, closer to the mean, for initial knee flexion. Initial knee flexion was deemed the most suitable variable for intervention for Participant 4, and was selected as the targeted variable.

The dependent variables torso lean and hip extension were considered less important to performance than final knee extension or initial knee flexion. As each participant's baseline data for the dependent variable initial knee flexion met the criteria for the targeted variable, there was no need to consider intervention on either of torso lean or hip extension

5.2 Changes in Level

5.2.1 Targeted Variable

Figure 5.1 shows the scores for initial knee flexion for each participant, plotted across the cumulative number of observations. The solid, vertical line indicates the introduction of intervention. The horizontal lines to the left and to the right of the solid, vertical line represent the baseline-testing phase mean and the intervention phase mean, respectively.

Based on visual analysis, a difference was found in level of scores following the introduction of intervention for each participant. Examined graphically, the most identifiable point in time at which the change in level became visible was the beginning of the second intervention session. It is worth noting that, for Participant 4, the change is less obvious than in the other three participants. For all participants, the change observed in level of the targeted variable was a decrease in the angle of initial knee flexion. This was the targeted change.

5.2.2 Non-Targeted Variables

No differences in level were observed for final knee extension, torso lean or hip extension (Figures 5.3 to 5.6).

5.3 Changes in Mean

5.3.1 Targeted Variable

Table 5.2 includes means for the targeted variable, for both phases, for each participant, with test-statistics for each comparison. The differences observed in level between baseline and intervention phase scores for the targeted variable (initial knee flexion) were accompanied by visually observed differences in mean. A t-test showed the observed differences in mean to be statistically significant ($p < 0.05$) in every case. The changes in means were also decreases; this was the targeted change.

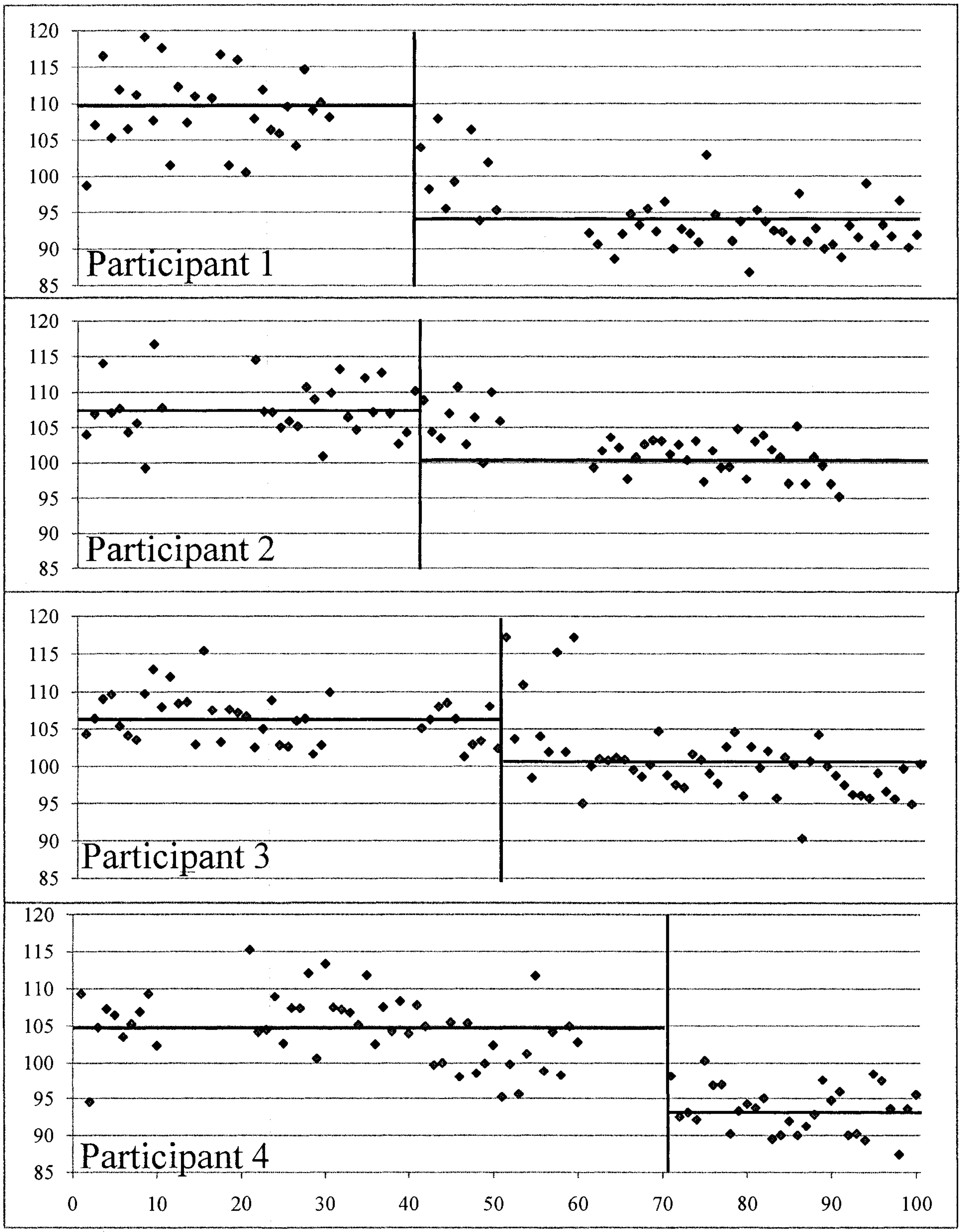


Figure 5.1 Angles of initial knee flexion (degrees) for each participant by observation.

Table 5.2 Participant data summaries for initial knee flexion.

Participant	Baseline Mean	Intervention Mean	Test Statistic	Significance
1*	109.8°	94.2°	$t_{(75)} = 12.896$	$p < 0.05$
1†	110.3°	94.2°	$t_{(65)} = 11.115$	$p < 0.05$
2	107.6°	102.1°	$t_{(68)} = 6.099$	$p < 0.05$
3	106.3°	100.7°	$t_{(88)} = 5.948$	$p < 0.05$
4	104.5°	93.5°	$t_{(78)} = 11.401$	$p < 0.05$

*Data from session using original intervention included in baseline data.
† Data from session using original intervention excluded.

5.3.2 *Non-Targeted Variables*

For participants 1, 2 and 3, no changes in mean were found for any of the non-targeted, dependent variables from baseline testing to intervention. For Participant 4, small but significant changes in mean were found in final knee extension ($t_{(74)} = -0.58, p < 0.05$) and for hip extension ($t_{(77)} = 2.938$, $p < 0.05$). Test statistics for all dependent variables, for all participants are included in Appendix C. In both cases, the change is a decrease in the angle, which is undesirable for those specific variables. As explained in section 5.1, data for Participant 4 on the non-targeted variables was erratic during both phases, which may account for these changes in means. These changes were not observed with visual analysis.

5.4 *Changes in Variability*

5.4.1 *Targeted Variable*

Slight changes in variability were observed for the targeted variable for all participants. These changes were seen to occur with the beginning of the second intervention session. In all participants, the observed change was a reduction in variability. Visual analysis of these results suggests that scores observed in the first intervention session tended to exhibit wider dispersion than did scores observed in subsequent intervention sessions. This is particularly prominent for Participant 1, whose first intervention session shows the widest dispersion of data over all nine sessions in which he took part.

5.4.2 Non-Targeted Variables

Figures 5.3 to 5.6 compare each participant's scores for each dependent variable. The vertical lines identify the beginnings of the first intervention sessions. There were no changes observed in the variability for the data collected for the non-targeted variables (final knee extension, torso lean or hip extension).

5.5 Changes in Trend

5.5.1 Targeted Variable

Figure 5.2 presents graphs of each participant's data for initial knee flexion including both baseline and intervention phase trend lines. The vertical lines represent the introductions of intervention, just as in Figure 5.1. Slight changes in trend between baseline and intervention conditions were observed for each participant. For all four participants, the changes in trend on the targeted variable were from to a more sharply decreasing trend. This was most prominent for Participants 1 and 2, for whom baseline trend lines were nearly horizontal.

5.5.2 Non-Targeted Variables

For final knee extension, slight changes in trend are seen for Participant 2. For hip extension, slight changes in trend are seen for Participants 1, and 2. Participant 3 exhibited no changes in trend in any non-targeted variables. Changes in trend for all three non-targeted variables are seen for Participant 4.

For Participant 4, final knee extension and hip extension scores showed decreasing trends during baseline testing and sharper decreasing trends following the introduction of intervention; these are congruent with the significant decreases in means on these variables for this participant, and account for the change in mean without corresponding changes in level. For Participant 4, for Torso lean, the direction of the trend changes from baseline to intervention (decreasing to increasing) but it should be noted that, as can be seen in Figure 5.6, scores for torso lean from the first intervention session are clustered alone, and score for the other intervention sessions are clustered together. The erratic nature of data for this participant likely accounts for the observed changes in trends.

5.6 Latency of Change

As has been mentioned in the previous sections, the changes that have heretofore been identified in mean, level and variability of the targeted variable scores, consistently occurred at the start of the second intervention session. The changes in level and mean were clear and unambiguous. Even though the changes in level in the targeted variable did not coincide with the change in condition, they were not gradual changes. They occurred at an identifiable point in time. The changes in level for initial knee flexion were immediate changes that occurred at the beginning of the second intervention session. Each of Figures 5.3 through 5.6 shows a single participant's scores for all four dependent variables. These allow comparison of what changes occurred (or did not occur) in each variable, for each participant. Figure 5.6 demonstrates the erraticism and clustering of data for Participant 4, mentioned in previous sections.

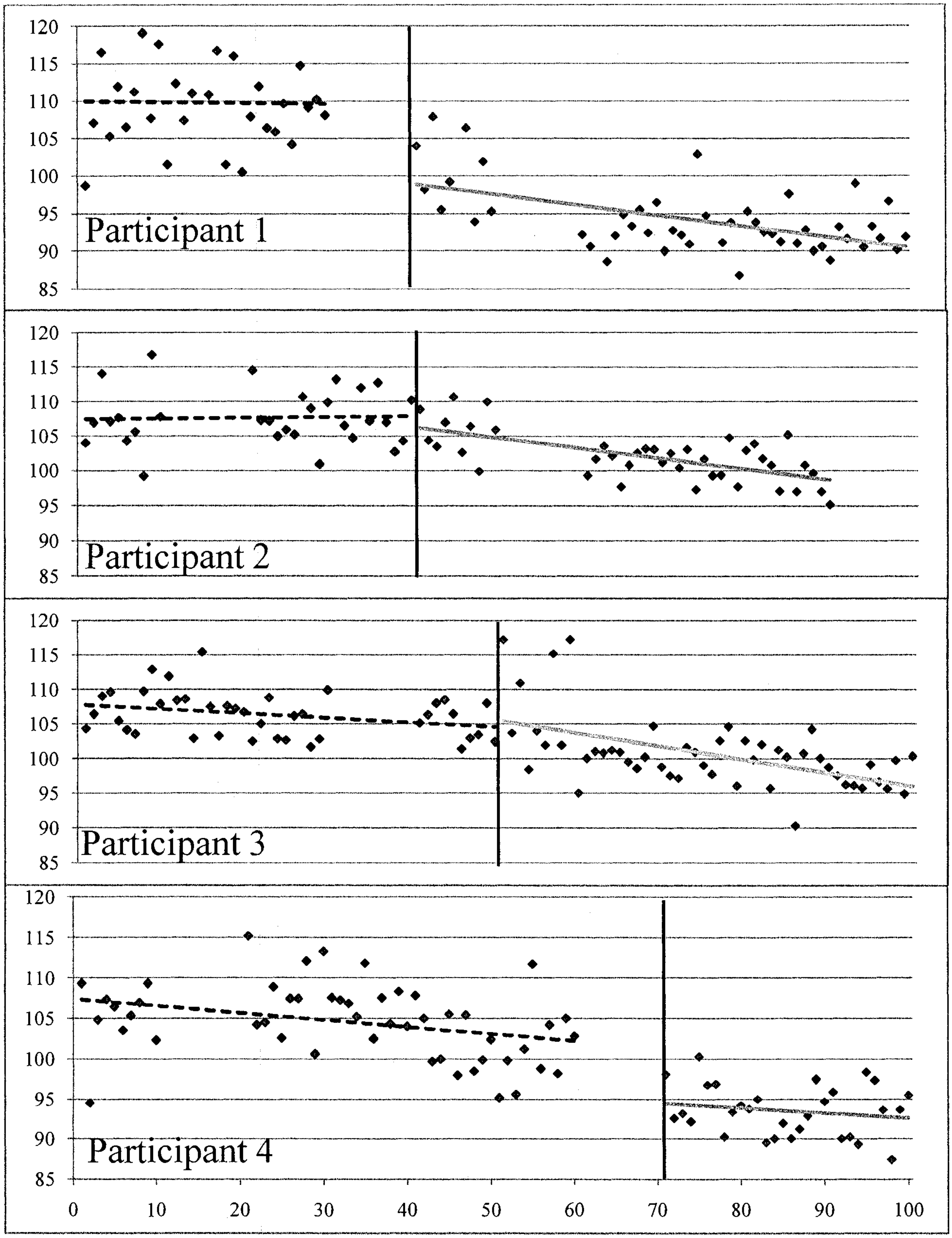


Figure 5.2 Angles of initial knee flexion for each participant, with trend lines.

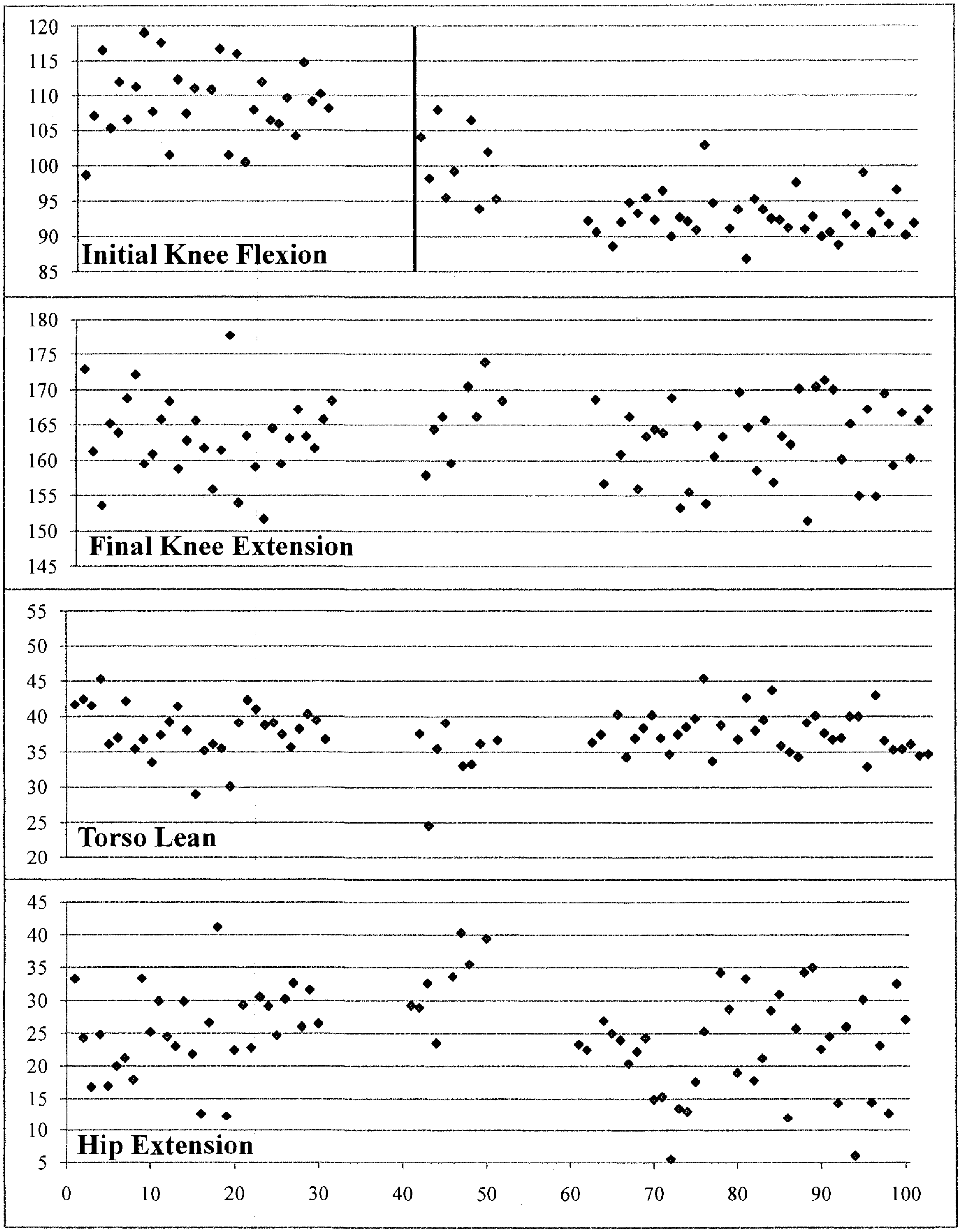


Figure 5.3 Scores for all dependent variables for Participant 1, across observations.

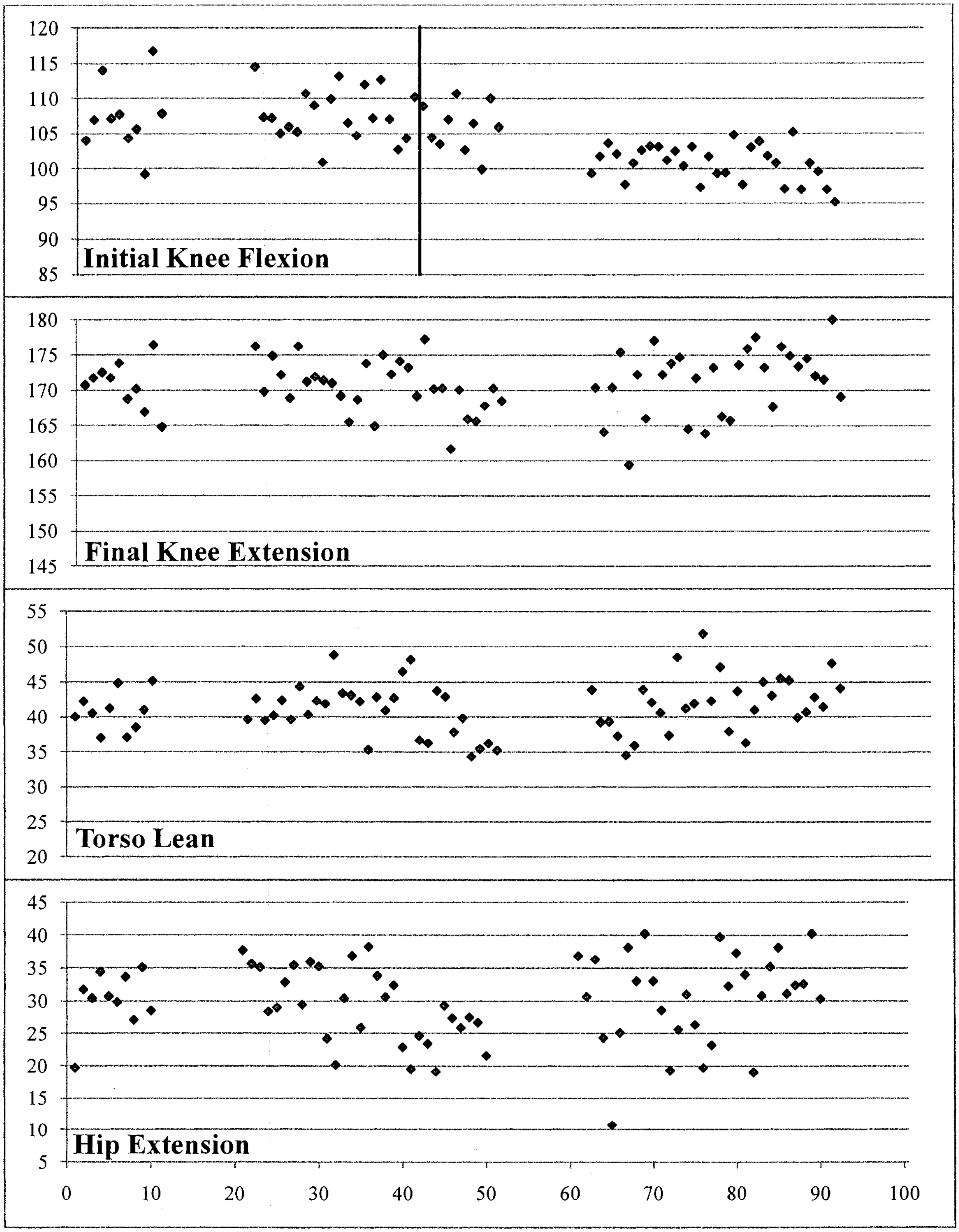


Figure 5.4 Scores for all dependent variables for Participant 2, across observations.

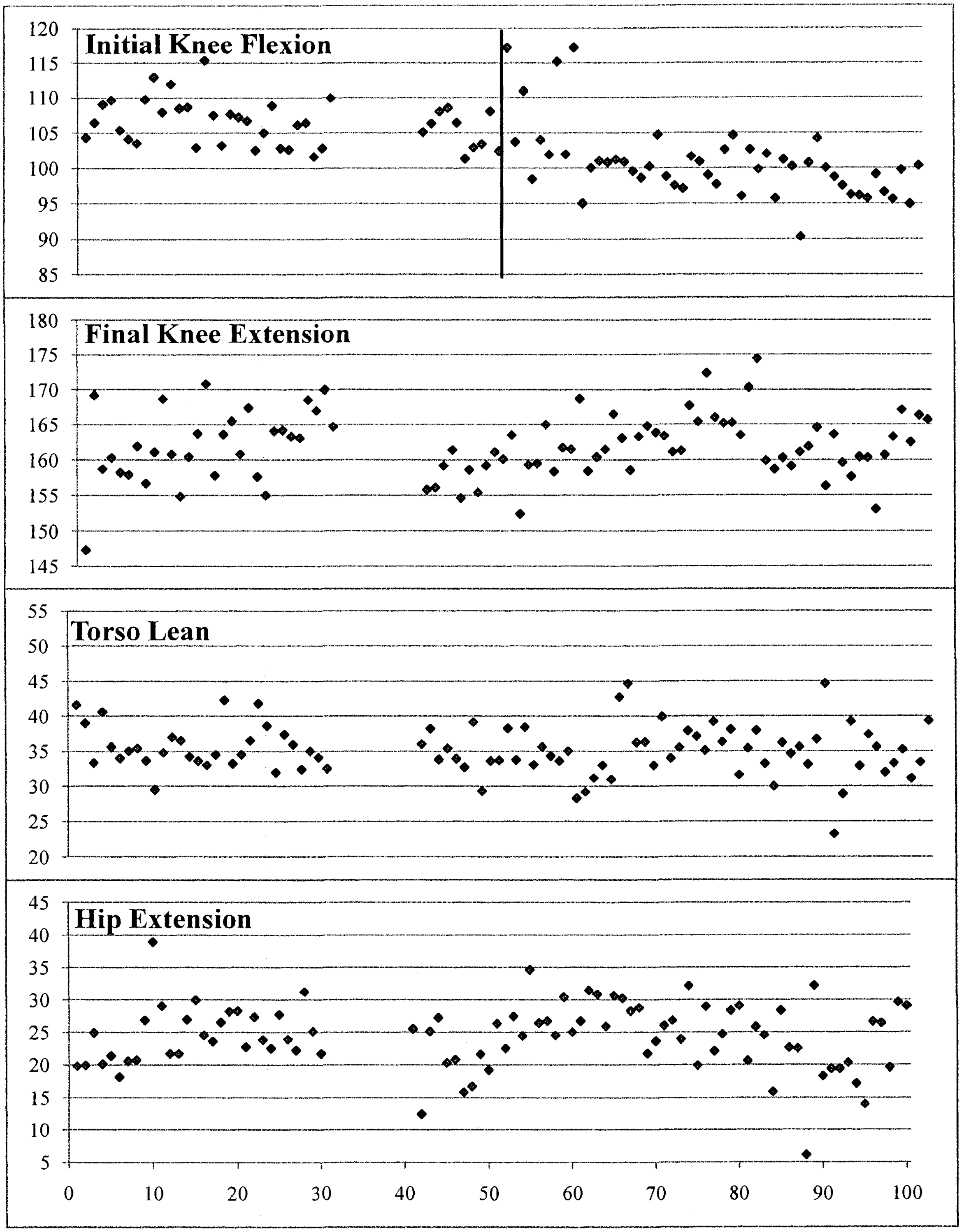


Figure 5.5 Scores for all dependent variables for Participant 3, across observations.

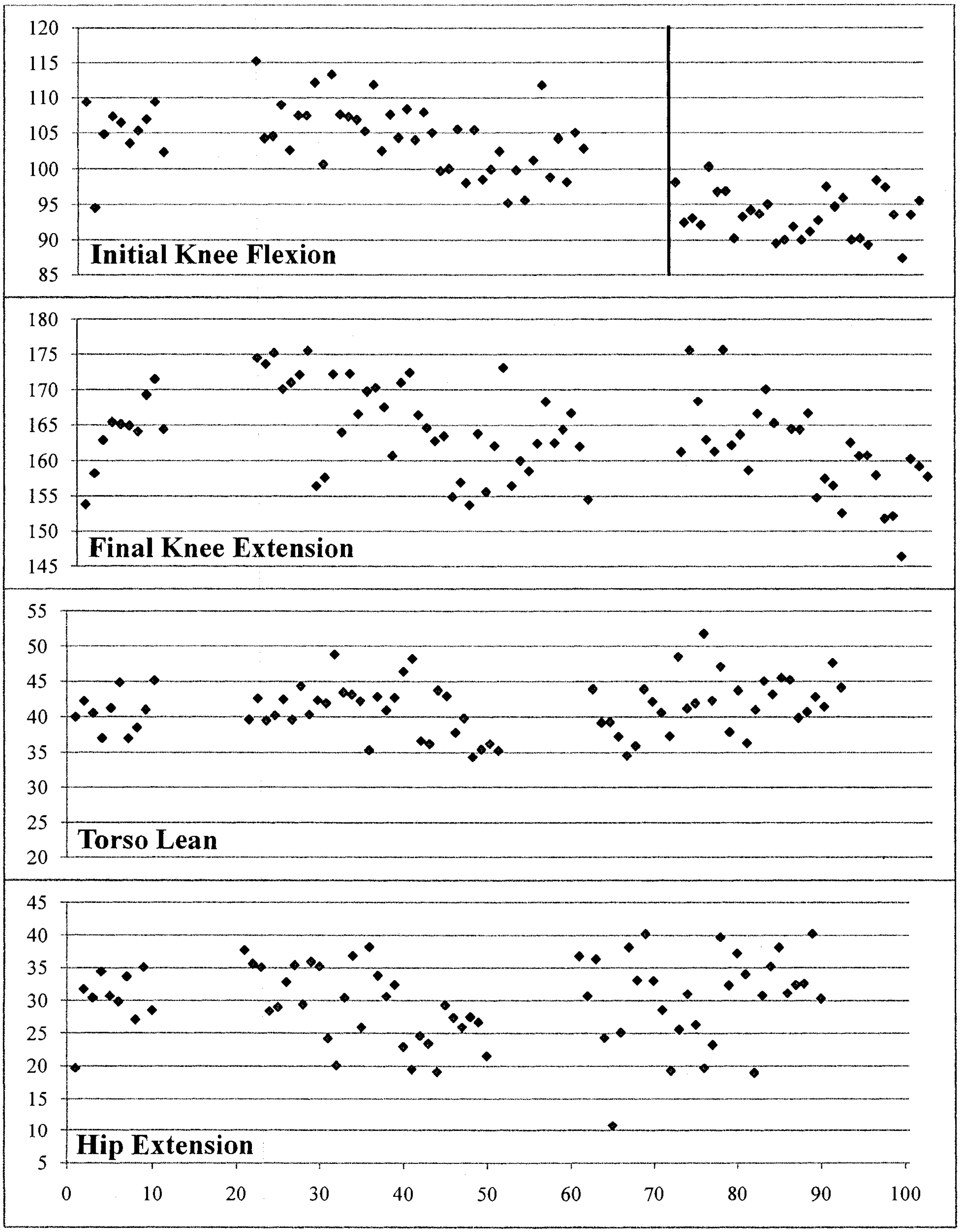


Figure 5.6 Scores for all dependent variables for Participant 4, across observations.

5.7 Results of the Questionnaire

Questionnaires were distributed to all four participants following the eighth observation session, and again following the 10th observation session. Of the questionnaires distributed after the eighth observation session, one was completed and returned. Of those distributed following data collection, three were completed and returned. These are included, in their entirety, in Appendix A. The information reported in the questionnaires suggests that the participants were able to understand the feedback as presented. Participants also reported mentally assessing their performance during the delivery of feedback, and thinking specifically about how to achieve the optimal knee angle immediately after receiving feedback. Participants 2 and 4 stated that the KP produced by Dartfish would be more useful to them if it were accompanied by verbal instruction as to how to correct the error identified in the KP display. Participant 4 noted that the physical demands of reducing the angle of initial knee flexion forced him to focus more on keeping his balance than on applying the feedback. Some scepticism about the permanency of the changes made by participants was also apparent. All three participants that returned questionnaires expressed a desire to see their strides from more than one angle.

6 DISCUSSION

6.1 Visual Perception

Much research has investigated learners' abilities both to perceive information from the observation of biological movement, and to apply that information once perceived. Self-modelling, or video training, studies generally show that there is some period of adjustment from the introduction of self-modelling to the time when changes in performance are observed (Burroughs, 1984; Magill, 1993; Wiese-Bjornstal & Weiss, 1992). These findings are demonstrative of a "learning curve" when it comes to perception and interpretation of self-model information. Processing and applying video feedback are abilities that must be acquired and can be improved with practice (Abernethy, 1988, 1989; Abernethy & Russel, 1987; Burroughs, 1984; Christina, et al., 1990; Hayes, Hodges, Scott et al., 2007). In the present study, participants having no previous experience with the type of KP presented exhibited a latent improvement in performance from the onset of the Dartfish intervention. This supports similar findings by previous researchers (Burroughs, 1984; Magill, 1993; Wiese-Bjornstal & Weiss, 1992).

Past researchers investigating video feedback have suggested using slow motion playback (Williams, 1989), multiple replays of video (Gould & Roberts, 1982), and superimposing point-light displays onto video (Hayes, Hodges, Scott et al., 2007) as methods to improve observers' abilities to "pick-up" information from video models. The KP delivered in the present study involved both of slow motion and multiple playbacks, as well as an angular measurement where vertices and end-points were at locations that would be marked in a point-light model of the hip, knee and ankle joints.

The latency of change to performance was rather brief, lending a certain amount of support to these suggestions by Williams, Gould and Roberts, and Hayes et al.

Changes in level for the targeted variable, initial knee flexion, were observed to occur following one complete intervention session. The first intervention session showed wider dispersion of scores for the targeted variable than did any of the following sessions; this was true across all participants. Also true for two of four participants, no change in level was observed from baseline testing to the first, intervention session. Though some change in level was observed on the first intervention session for the other two participants, the *final* change in level was observed upon the beginning of the second intervention session across all of the four participants. Since participants had no previous experience with the type of KP presented to them, it stands to reason that this first encounter with a novel interface was spent developing a cognitive strategy for processing and applying a new form of information. If that is the case, then at the second intervention session (where the final level changes were observed) that cognitive strategy was fully implemented, the visual KP was applied to participants' existing cognitive representations of the forward skating stride, and improved performance followed.

The changes in performance were rather abrupt, suggesting that participants did not have difficulty interpreting and applying the feedback. This was reflected in questionnaire responses, where participants indicated being able to understand the KP. It also aligns nicely with findings by Abernethy (1988; 1989; Abernethy & Russel, 1987), Hayes et al. (2007), and others (Ashford et al., 2007; Wiese-Bjornstal & Weiss, 1992) who state that adult and expert performers are better able to perceive and utilise visual information than are their younger and/or less skilled counterparts.

6.2 *Examining Changes*

There are many inferences that can be made from the observed changes. The potential causes of those changes will be discussed here. Results for Participants 1 and 4 differed from those for Participants 2 and 3. The natures of the differences and similarities in results across participants will be explored in this section.

For participants 1 and 4, a change in level was evident on their first intervention sessions, but in both cases, the *final* change in level occurred at the second intervention session, as for Participants 2 and 3. For Participant 1, it should be noted that what was considered to be his first intervention session was the first session with the *revised* KP procedure, which is the procedure employed for all participants, rather than the original procedure that was abandoned. This means that Participant 1 had been exposed to a form of visually augmented video feedback during his final baseline testing session. In that session, no change in level was observed from the previous session on any variable, but it may explain why he seemed to have more success than other participants in applying the feedback during his first intervention session. For Participant 4, being the last to have the intervention introduced, he may have anticipated that his targeted variable would be initial knee flexion, as it was for the other three participants. The nature of the KP was also somewhat relevant to Participant 4's academic programme, and he was very enthusiastic about the study and the technology. Motivation may have been a factor in the results he achieved.

One similarity between participants 1 and 4 is that each of them missed the last observation session before the intervention was introduced. Another is that, of the four participants, they had more positive attitudes toward Dartfish training. These may have been factors for participants 1 and 4 who showed some change in level for the targeted variable on their first intervention sessions, a change not exhibited the data for participants 2 and 3. It should be reiterated here that the *final* changes in level were observed at the second intervention session for all participants.

It is important to recognise that changes to the non-targeted variables, final knee extension, torso lean, and hip extension, were few. The small decreases in means for Participant 4 for hip extension and for final knee extension may be attributable to his generally erratic data. He also indicated on his questionnaire that he had difficulty maintaining balance when trying to accomplish the targeted change to initial knee flexion. He may have made changes, purposefully or not, to other aspects of the stride to accommodate the targeted change. However, no visually identifiable changes were observed on any of the non-targeted variables for any participant. It has been demonstrated that self-modelling on its own can lead to improved performance (Hodges et al., 2007). If changes had been observed across more of the dependent variables, it would have suggested a large effect of self-modelling alone, rather than an effect of KP. However, such changes were not observed in the non-targeted variables. With changes to the non-targeted variables being few, and changes to the targeted variable being consistent, the results of this, initial Dartfish investigation suggest that changes were related to the KP rather than to the video alone.

6.3 Implications for Observational Learning

Modelling and demonstration are believed to be effective because they facilitate observational learning. Combining modelling with other forms of feedback has been shown effective in some cases. Wiese-Bjornstal and Weiss (1992) reported that adding auditory cues (e.g. look at the model's hands) to video modelling of a softball pitch resulted in the greatest improvements in participants' emulations of the video model; that study also shows, however, that the immediate effect of introducing the auditory cues was a reduction in participants' compliance with the model. This indicated a period of adjustment to the combined audio-visual feedback, which was proposed to be due to a difficulty in aligning performance information received through two sensory systems. Magill (1993) showed the combination of verbal KP and video modelling to be no more or less effective than either verbal KP or video modelling alone. In both of those cases, an expert model was used with novice participants. Baudry et al. (2006) combined expert modelling and self-modelling with intermediately skilled participants via Dartfish's split screen capability. Using Dartfish's angle measurement tool, they also combined verbal and visual KP. A participant's body alignment (on the double-leg pommel horse circle in gymnastics) was measured on-screen, and a coach indicated verbally how the participant's body alignment differed from the expert's. This experimental procedure was conducted in addition to ordinary coaching with the control condition involving *only* the ordinary coaching. The experimental condition, which combined expert and self modelling with audiovisual KP, resulted in greater improvements to performance than the control condition on both post-test and retention test.

These studies suggest that observers of a video model can simultaneously utilise KP with the model, and that this can lead to greater improvements in performance than verbal KP or video modelling alone. The Magill (1993) study differed from the Baudry et al. (2006) and Wiese-Bjornstal and Weiss (1992) studies in that the KP was not combined with modelling simultaneously. The different results in these two situations are logical when one considers that, during observation of a movement, the cognitive representation is accessed in a similar way as when a skill is being executed (Beauchamp et al., 2003; Hodges et al., 2007; Vogt & Thomaschke, 2007). By presenting KP or cues during observation of the model, they are necessarily fixed to a temporal position in the cognitive representation. Since coordination of the auditory and visuomotor systems is difficult, as shown by Wiese-Bjornstal and Weiss, a logical conclusion is that simultaneous, visual presentation of both the model and KP would be more efficient. The short latency of changes in this study, and the finding of Baudry et al. suggest that efficiency. It is possible that, in the present study, unifying KP and modelling into one, *visual* presentation better facilitated the perception, cognitive organisation and active implementation of performance information.

6.4 Limitations and Potentially Confounding Factors

Both the design and the field setting of the present study introduced some potentially confounding factors and limitations. These must be considered when weighing the results.

Timing and external influences on performance were potential confounders on the results. The observation sessions had to be orchestrated around participants' class and practice schedules. The times of day, and days of the week varied and, as can be seen in Figure 4.1, participants did not attend all of the same sessions. This could have introduced effects of timing on the results. The study was conducted during the hockey season. This means that normal instruction from coaches could not be eliminated or controlled. Amount of practice was also a factor beyond the researcher's control. Neither outside instruction nor amount of practice was delimited. Other influences on performance may have been present. Participants may have discussed the intervention, or their results, attitudes and experiences amongst each other. The results of recent games or academic stressors such as mid-term examinations (which fell during data collection) may have temporarily affected motivation and/or performance. These may have been threats to internal validity.

Limitations are enumerated in Section 1.2, so they will be examined only briefly here. The small sample size (n = 4) is not generalisable to a broad population. That same small sample size prevented the inclusion of control conditions; the effects of modelling, and KP and attentional cueing to the targeted variable were not isolated. Effects upon a specific motor skill were the subject of this investigation; while these results may have influence on future investigations into Dartfish and other forms of visually augmented feedback, this study's results are not directly relevant to other motor skills. All of these limitations impact external validity. In single subject research, external validity is achieved by direct or systematic replication of the results, rather than by probability statistics or hypothesis testing (Kazdin, 1982). Further investigation of the effects of visually augmented video feedback is required to establish external validity.

7 SUMMARY AND CONCLUSIONS

The purpose of this study was to determine if the delivery of knowledge of performance through the use of Dartfish video software resulted in a targeted change in performance on a specific, kinematic variable during forward skating. A single subject, multiple baseline, across participants design was used. The study involved four participants, all of whom were high performance ice hockey players, selected from the Lakehead University varsity team. During each session each participant completed 10 trials of forward skating at his maximum velocity. During the intervention phase, feedback was delivered immediately following the first, third, fifth, seventh and ninth trials. Feedback was delivered as a measurement of the angle of initial knee flexion and a visual representation of an optimal angle, both superimposed over a video replay. The targeted change was a lower angle of initial knee flexion.

Key results of this study were: (1) the targeted change in performance was observed for all participants, (2) for all participants, the targeted change was observed to occur at the beginning of the second intervention session, and (3) few changes were observed in the non-targeted variables. With visual analysis, changes were observed only on the targeted variable.

From these results, several inferences can be made: (1) Participants were likely able to utilise the KP to achieve the targeted change. (2) A period of adjustment after the introduction of intervention preceded the targeted change. (3) Because changes for the non-targeted variables were few, changes for the targeted variable may have been related to the KP delivery, rather than to self-modelling alone. (4) The short period of adjustment between the introduction of the invention and the change in level on the targeted variable suggests that participants were able to perceive and process the KP efficiently; this may be related to age, skill level and experience.

As has been mentioned, only one previously published study directly investigates the effectiveness of training with Dartfish. There are now two studies that suggest Dartfish training positively affects athletic performance. Replication of these results is necessary to achieve external validity of this finding (Kazdin, 1982). This investigation is in its infancy, leaving almost infinite directions for future research.

Despite already wide use, not only in sport (Bartoli et al., 2004; Baudry et al., 2006; Demeris, et al., 2002; Hars & Calmels, 2007; Hayes, Hodges, Scott et al., 2007; Hodges & Williams, 2007; Kokaram, et al., 2006; Sheppard, 2006; Thomas & Stratton, 2006; Williams & Hodges, 2005) but also in clinical and research applications (Abercrombie et al., 2006; Miller & Kang, 2007; Petersen et al., 2007; van Vuuren-Cassar & Lamprianou, 2006; Womersley & May, 2006), a search of the relevant literature returned no studies or reports on the reliability and validity of measurements made with Dartfish software. The pilot investigation for this study was very specific to the needs here, and reliability and validity analyses are important areas for the attention of future researchers. These should include laboratory and field settings. A study comparing reliability and validity of measurements between participants wearing and not wearing bulky, protective clothing or equipment would be of particular relevance to future studies involving ice hockey, or other sports that require bulky equipment.

The two existing studies (this, and Baudry et al., 2006) investigated effects of Dartfish on motor skill performance. Though Baudry et al.'s study is more congruent than the present one with the motor learning paradigm, studies falling squarely in that arena are a necessary step. Studies in laboratory environments will allow researchers to isolate a skill, and to control for effects of self-modelling and/or KP alone. Studying the effects of visually augmented video feedback for children compared to adults, and for participants at different stages of learning would be of particular benefit, as they would help coaches to understand when tools like Dartfish are most useful and appropriate. These could be group-designs, or matched-subjects single-subject designs.

Future performance studies should utilise designs that, systematically or directly, replicate the present design; these are necessary to establish external validity of these results (Kazdin, 1982). Direct replications of this study would be new studies following the same procedures as the current study. Systematic replications of this study would include similar studies of different skills, participants and environments. It will also be useful to study different ways of generating feedback with Dartfish software. Different types of Dartfish feedback can include use of solely qualitative feedback, attentional cues (e.g. clone rectangles, highlights), different ways to represent optimal performance, or no representation of optimal performance.

All of the avenues heretofore described should be followed with studies investigating wide ranges of participants, movements and environments to create a broad and robust body of research on technologies that are becoming ever more accessible and present.

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APPENDIX A:

QUESTIONNAIRES RETURNED BY PARTICIPANTS

Participant 1

Post-study Questionnaire

1. Were you able to understand the feedback delivered with the computer and Dartfish? What changes, if any, would you make to the way the feedback was presented?

   Yes I could understand he feedback.

2. How helpful did you find the Dartfish feedback, and how effectively were you able to apply it?
   The feedback was good at showing me what I was doing wrong but does not provide you with how to adjust it making it difficult to apply. Based on the fact I have been skating the same way since I was a kid. However I feel I was able to adjust according to the feedback I received.

3. What did you think about:
   a. While watching yourself on screen and getting feedback with Dartfish?
      How to get to the optimal

   b. Right after getting Dartfish feedback?
      Bending my legs to reach optimal

   c. While skating?
      How many laps I have left

4. Please write a short assessment of your forward skating ability based on your performances up until now. Include any change you have perceived in your skating (even if it's unrelated).
   Well I was able to reach the optimal within a degree or two every time which would indicate I improved over the course of the study. However without continuing to skate like that over extended periods of time I will just go back to the way I was taught and know how to skate.

5. Comments:

Please add anything else you would like to say about Dartfish, based on your experience so far.

I am not sure I fully understand what this study is or is proving so I am interested in seeing the results and what they mean. Overall it was fun to be a part of. As for the skating for each session if it were under ten laps that may have been less exhausting for the participants. Fewer laps would also limit any fatigue that may cause the participant to change their stride. .

Participant 2
Mid-Study Questionnaire

1. Were you able to understand the feedback delivered with the computer and Dartfish? What changes, if any, would you make to the way the feedback was presented?
   The feedback allowed me to see my stride compared to an optimal skating stride. It was easy to understand, however somewhat difficult to change the way I skate, you get so used to skating the same way when it has been for so long. My only argument (which eventually was changed) was the fact the optimal angle kind of seemed unachievable and not very practical. Furthermore, I may have been nice to see my stride at different angles in order to make the necessary improvements.

2. How helpful did you find the Dartfish feedback, and how effectively were you able to apply it?
   The feedback was helpful in a sense that I could see what I needed to do to achieve the optimal stride. However, to achieve the bottom half of the angle, my leg would have to be bent in a very uncomfortable skating position.

3. What did you think about:
   a. While watching yourself on screen and getting feedback with Dartfish?
      Focused on my current stride, and watched for the necessary improvements. Mentally compared the way my knee bent to the optimal skating stride.

b. Right after getting Dartfish feedback?
   Thought of how I could change what I was previously doing. Questioned whether the optimal stride was actually achievable.

c. While skating?
   Pretty much just tried to do a full stride, and stay consistent with my previous laps, just incorporating minor changes each time.

4. Please write a short assessment of your forward skating ability based on your performances up until now.
   I think I have a pretty good skating stride. I have played hockey at very high levels and have always been able to play on top-lines. I may not be the fastest guy on the teams I've played for; however my legs are relatively short. My game is based on puck possession so I spend a large part of playing hockey with the puck on my stick. I personally think skating with a puck is more important than skating with a fast stride, because it requires more skill, agility, and overall composure.

5. Comments:

Please add anything else you would like to say about Dartfish, based on your experience so far.

So far I think it has been a positive experience, but with possibly look at my stride with different angles, and being provided with on-ice feedback and direction it would be much easier to make the necessary changes rather than be simply watching it on video. I think the software itself is very good from what I have seen, and I'm sure there are several features that I am unaware of. Will I ever change my stride? At this point in my current I think it is highly unlikely (as I have been skating the same way now for 19 years), but with that being said, it's interesting to be able to view myself using the Dartfish technology.

Participant 2
Post-study Questionnaire

1. Were you able to understand the feedback delivered with the computer and Dartfish? What changes, if any, would you make to the way the feedback was presented?

The feedback was alright. It was good to see the stride from a different point of view. I would like to see it though from many angles rather than just the one. It is also hard to decide how to change it based on just the video.

2. How helpful did you find the Dartfish feedback, and how effectively were you able to apply it?

Like previously mentioned it was difficult to make changes without any personal guidance. I have been skating the same way for several years, so making changes while just watching video is hard. However, I think I tried the best I could under the time period.

3. What did you think about:
    a. While watching yourself on screen and getting feedback with Dartfish?

    Understand the changes that needed to be made to have an optimal stride.

    b. Right after getting Dartfish feedback?

    Preparing for my next lap, and thinking about correcting the necessary mistakes.

    c. While skating?

    Pretty much nothing except, keep a steady speed, and focusing on correct strides.

4. Please write a short assessment of your forward skating ability based on your performances up until now. Include any change you have perceived in your skating (even if it's unrelated).

I have always been a relatively fast skater, and have played at high levels of hockey. I always think there is a need to be a good skater in order to be successful in hockey, but speed and stuff isn't the most important as skill, vision, and a nice stride. I guess I would like to be somewhat faster but thus far I've been pretty happy with my skating ability.

5. Comments:

Please add anything else you would like to say about Dartfish, based on your experience so far.

It was nice to see myself on video, but I think Dartfish with the combination of professional skating instruction would be much more beneficial. The software definitely has some advantages, however I think it needs some work technologically. Furthermore, I think the addition of different camera angles would help the overall analysis.

Participant 4

Post-study Questionnaire

1. Were you able to understand the feedback delivered with the computer and Dartfish? What changes, if any, would you make to the way the feedback was presented?

    –make the video slower

    - make 2 video angle

2. How helpful did you find the Dartfish feedback, and how effectively were you able to apply it?
They were hard to apply since skating that low demanded a lot of balance

3. What did you think about:
    a. While watching yourself on screen and getting feedback with Dartfish?
    b. Right after getting Dartfish feedback?
    c. While skating?

    I didn't see any difference when trying to apply it right away after seeing myself on the video. I was only focusing on not falling.

4. Please write a short assessment of your forward skating ability based on your performances up until now. Include any change you have perceived in your skating (even if it's unrelated).

If would have prefer doing the 50 sprints without applying the theory and 50 sprints in a row while applying the theory. By taking the time in both cases, it would have been possible to see if there was any difference.

5. Comments:
Please add anything else you would like to say about Dartfish, based on your experience so far.

Other ideas such as the coordination of the members, the position of the skate at the neutral states (the skate on the ice while the other is pushing) and the motion of the ankle at the end of the pushing could be good ideas to be developed.

APPENDIX B:
PILOT INVESTIGATION: RELIABILITY AND VALIDITY ANALYSIS

INTRODUCTION

Demonstration is the most commonly used method of presenting movement information in sport settings (Williams & Hodges, 2005). Technologies such as Dartfish software are rapidly changing the ways coaches can deliver both demonstrations and feedback. Dartfish software, specifically, allows a coach, trainer, or other user to deliver feedback in the form of measurements, highlights and other superimposed features onto video of an athlete's performance. The positions of joints and body segments are important in a motor skill, and can be described and defined by relative and absolute angles. These new methods have yet to receive substantial attention from researchers, and little is known about their effects on athletic and motor performance. These effects need to be tested, so that practitioners can know whether, and when, these tools are useful in instruction and training. To this end, this study has been undertaken testing the effects of feedback in the form of measures of the knee angle of an ice hockey player's skating stride. Important to this study, and indeed to researchers and coaches alike, is an understanding of how well Dartfish measurements can be trusted.

Determinations of validity and reliability are both carried out by comparing two sets of measurements. Validity is the accuracy of a tool's measurements, and reliability is the repeatability, or consistency of a tool's measurements. Therefore, in validity testing, the measures are from two different tools, while for reliability repeated measures with the same tool are analysed (Vincent, 1999). The fundamental question, in both analyses, is how much error can be expected with a given tool. Therefore, in either case, the degree of *agreement* between the two sets of measurements is the result of interest.

Analysis

The Altman-Bland test uses difference scores to evaluate error directly. The Altman-Bland test are the primary analysis in this study, and conducted using the Analyse-it (Analyse-it

v. 2.08, Method Evaluation Edition, Leeds, UK: Analyse-it Software Ltd.) statistical programme for Microsoft Excel (Microsoft® Office Excel® 2007 (12.0.4518.1014) part of Microsoft Office Professional Plus 2007, Seattle, WA: Microsoft Corporation). Because of some difficulties that arose in analysis, *ICC* was also used to demonstrate agreement in some cases. The intent of this was to allow comparison of different results within the study, and how differences in the limits of agreement are reflected in changes to the *ICC*. ICC's were calculated using SPSS 16.0 (SPSS for Windows, Rel. 16.0.1. 2007. Chicago: SPSS Inc.).

PURPOSE

The purpose of this study is to establish the degree to which angular displacements, with particular attention to the relative angle of the knee, measured using Dartfish software are valid, and their degree of repeatability by a specific user.

EXPERIMENT 1

Method

To test their validity, angular measurements made by Dartfish, using stationary objects, will be tested for agreement with reference measures. Angles between marked points on a calibration tree from Vicon Motion Systems (Oxford, UK: OMG Plc) was measured, and these measures compared to the reference measurement. The surveyed, reference measures were taken as true, and so a test of absolute agreement was appropriately conducted in this case.

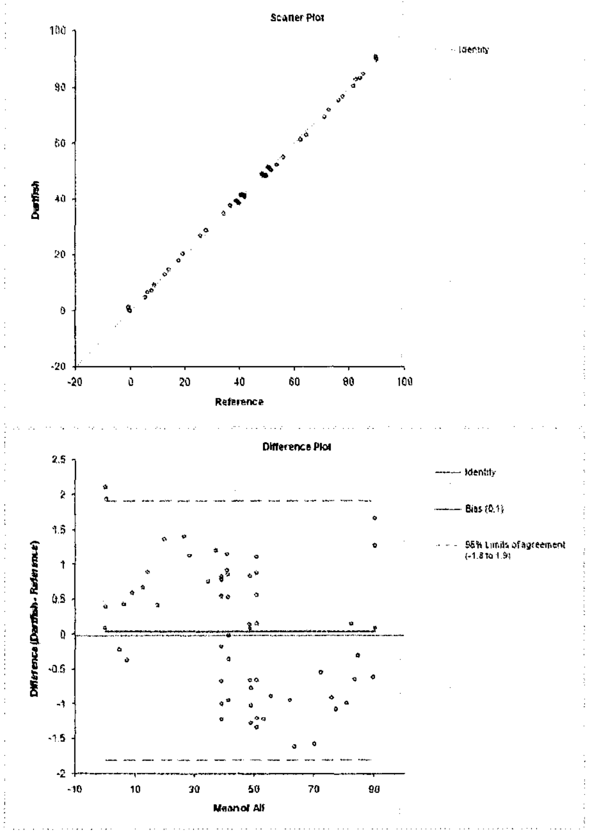


Figure B1. Identity (top) and difference (bottom) plots for *Experiment 1.*

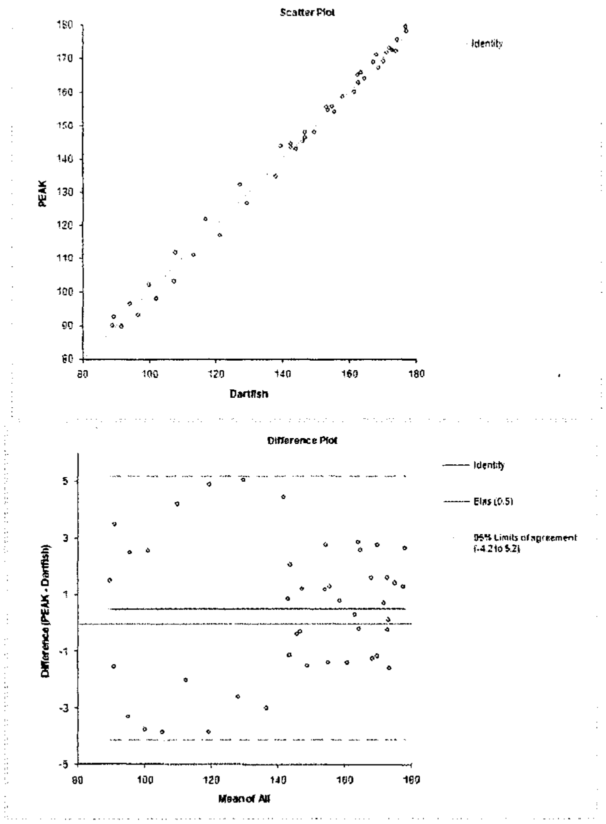


Figure B2. Identity (top) and difference (bottom) plots for *Experiment 2.*

Results

Agreement was assessed by Altman-Bland limits of agreement, using the Analyse-it programme for Microsoft Excel. 95% Limits of Agreement between the surveyed, reference values for the angles, and the Dartfish measured values for the same angles were -1.81° to 1.92°. There was a bias of 0.5° (Figure B1). This result means that, with 95% confidence, it can be expected that angle measurements with Dartfish software will be within the range: 0.5-1.81° - 0.5+1.92°. In the case of analysing joint or segmental angles in a sport skill, this would normally be an acceptable error. Future studies would show whether these results, and in particular the bias, are consistently exhibited by Dartfish, angle measurements.

EXPERIMENT 2

Method

Participant

This test of the validity involved one participant, selected from the Lakehead University varsity track and field team.

Procedures

In this test of validity, measures made with both Dartfish and Vicon software of the relative angle of the participant's knee were compared. The participant ran for a period of 2 minutes, at a consistent and comfortable pace chosen by the participant, on a treadmill with no incline. These trials were videotaped on a MiniDV camcorder, and the videographic data from the MiniDV tape was later converted to an .avi video file for use with both the Vicon and the Dartfish software. The participant wore reflective markers on the following anatomical landmarks: (1) greater trochanter of the femur (hip) (2) lateral condoyle of the femur (knee) and (3) lateral malleolus of the fibula (ankle).

These markers were used to take measurements of her absolute and relative movements using both the Vicon and the Dartfish software. Measures of absolute and relative angles made with Dartfish software were compared to corresponding measurements calculated using the Vicon software. The similarity (or dissimilarity) of measures from the two different software programmes was assessed. Both Vicon Motus and Dartfish ProSuite make indirect measurements that are subject to human error. Therefore, agreement, rather than absolute agreement, was tested

Results

A significant correlation, ($ICC = 0.998$, $p < 0.05$) was found, with a higher coefficient than for the unadjusted data. The Altman-Bland test for limits of agreement found a bias of 0.5205°, with 95% limits of agreement from -4.15° to 5.19° (Figure B2). This indicates approximately half of the range of error indicated by the test before the datum was deleted.

Experiment 3

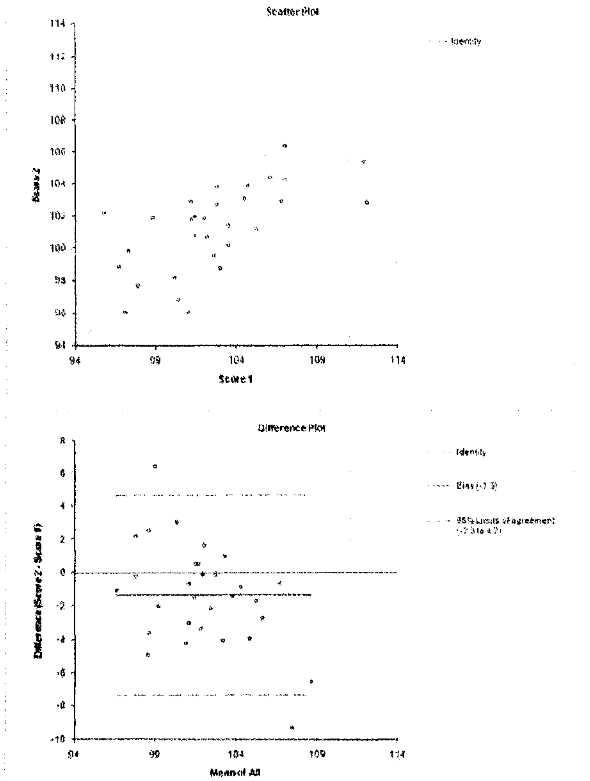
Method

Participants

This segment of the study involved 20 participants, selected from the Lakehead University varsity men's ice hockey team. Participants were selected from this team because this is also the population from which participants in the subsequent, performance study would be drawn.

Apparatus

Each participant skated the length of a standard ice hockey rink three times at his maximum velocity. All trials were captured videographically in the sagittal plane, on three MiniDV camcorders. The camcorders were staggered so that the field widths overlapped. The use of multiple, staggered camcorders ensured that a full, skating cycle (two strides, one with each leg) was captured for each participant, while maximising image size. The MiniDV video was converted to digital .avi video files. Trials from the two cameras that captured larger image sizes than the other were used for angle measurements. These trials were analysed, measuring one angle for each cycle. Only measures of the left leg (closest to the cameras) were used. Measures were taken at the instant of maximal extension of the propulsive leg.



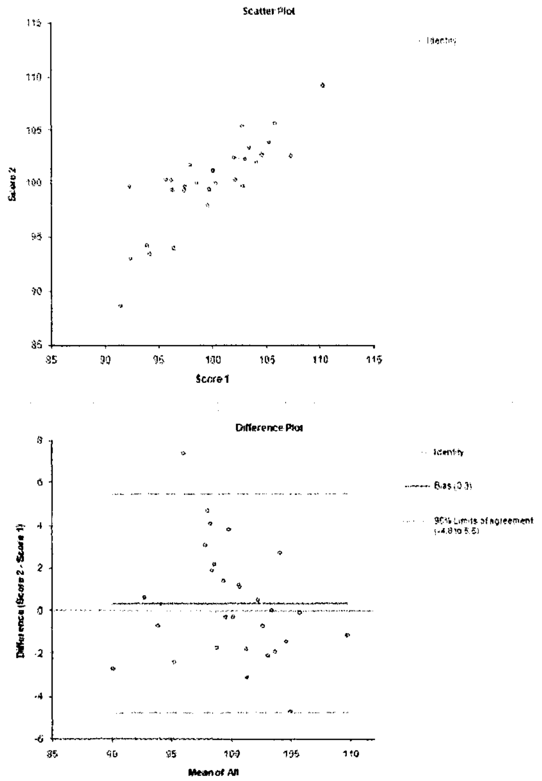


Figure B3. Identity (top) and difference (bottom) plots for low-resolution video (n=30) for Experimentaaa 3

Figure B4 Identity (top) and difference (bottom) plots for high-resolution video (n=3a0) for Experiment 3.

There was a concern that a learning effect on the part of the operator, and poor image quality due to low shutter-speed (1/60 s or 1/180 s, depending on lighting conditions) of the camcorders, confounded the results. Thirty trials were randomly selected from those recorded for the reliability analysis. An additional 30 trials were randomly selected from similar data that had been captured for another study, using a higher shutter-speed (1/500 s, or 1/750 s, depending on lighting conditions). This process was repeated on a second day. A comparison of reliability results for the lower-resolution video to reliability results for the total sample of sixty pairs of measurements indicated whether the researcher's repeatability with these measurements improved. A comparison of the repeatability results from the 30 trials with better video quality to repeatability results from the 30 trials with poorer video quality indicated whether the video quality was a confounding factor in reliability analysis.

Results

Intra-operator reliability was tested using limits of agreement. The data assessed included all angles measured as a single data set, because this produced a normal distribution of differences, which is necessary for the Altman-Bland procedure (Bland & Altman, 1986). For the full sample of sixty pairs of angles, encompassing both the original video and the new video, a bias of -0.49° was found, with 95% limits of agreement being -6.27° to 5.23°. Analysing the 30 angle measurements from the original, poor quality video, a bias of -1.31° was found, with 95% limits of agreement being -7.35° to 4.73° (Figure B3). Analysing the 30 angle measurements from the new, higher quality video, a bias of 0.33° was found, with 95% limits of agreement at -4.8° to 5.46° (Figure B4).

SUMMARY DISCUSSION

Both validity and reliability testing results support a reasonable level of confidence in angle measurements, and more specifically measurements of the relative angle of the knee, obtained with Dartfish software. Comparison to a reference measure, as in the first validity test, showed that 95% of measurements with Dartfish would include an error within less than two degrees of the true measure. Dartfish angle measures agree with Vicon angle measurements, (which are also indirect) within approximately five degrees, 95% of the time, based on the adjusted data. When video quality and learning effects are accounted for, Dartfish measurements, of athletes in full hockey equipment, are reliable within less than six degrees, 95% of the time, which is very near the level of agreement between Dartfish and Vicon measurements.

Validity testing showed good agreement between Dartfish and reference measures. In the comparison of Dartfish measures to Vicon Motus measures, the error of both methods is included in the resulting agreement. It should also be noted here that, the Vicon Motus measures were calibrated based on reference points on the treadmill in the video. The direct reference added to the video data did not have a suitable, vertical distance for proper calibration. This likely resulted in the locations of the calibration reference points less accurate than would be normal when using Vicon Motus for analysis (Scholz, 1989; Shrout & Fleiss, 1979). If this is the case, it will have resulted in a greater than normal error in the Vicon measures. There is no way of assessing the magnitude of such a difference in error, but as the agreement between Dartfish and Vicon is good, it is reasonable to assume that it is not substantial. Any such 'additional error' in this particular set of Vicon Motus data would be more likely to decrease than to increase agreement. Therefore, the results of the Dartfish-Vicon Motus comparison can be taken to be correct, and perhaps even considered a rather liberal estimation of agreement.

No prior studies have been published assessing the accuracy or reliability of measures made with Dartfish ProSuite software. To establish an expected range of error firmly, the results must be repeated in various settings for various types of skill. It would be a great asset to coaches and other users to know how different conditions may affect the accuracy and reliability of their measurements, so that they may make the best possible use of this tool. This is a humble beginning to that process of investigation.

Of most direct importance here, as this is a pilot study, is whether measurements made with Dartfish ProSuite software, of the relative angle of an athlete's knee are sufficiently valid and reliable for the purposes of the subsequent performance study in which that is the variable of greatest interest. The results here show that Dartfish measurements can be expected to be valid within approximately five degrees of the true angle, 95% of the time. Further, they are reliable in the hands of the operator who will conduct the study, and make all measurements in the study, within less than six degrees, 95% of the time. That result includes both human error from one measurement to the next, and the error of the software itself. For the purposes of the performance study to be completed subsequent to this pilot study, this is a sufficient level of validity and reliability.

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APPENDIX C:
MEANS COMPARISONS FOR DEPENDENT VARIABLES

Baseline and Intervention Means and Test Statistics for Initial Knee Flexion

Participant	Baseline Mean	Intervention Mean	Test Statistic	Significance
1*	109.8°	94.2°	$t_{(75)} = 12.896$	$p < 0.05$
1†	110.3°	94.2°	$t_{(65)} = 11.115$	$p < 0.05$
2	107.6°	102.1°	$t_{(68)} = 6.099$	$p < 0.05$
3	106.3°	100.7°	$t_{(88)} = 5.948$	$p < 0.05$
4	104.5°	93.5°	$t_{(78)} = 11.401$	$p < 0.05$

Baseline and Intervention Means and Test Statistics for Final Knee Extension

Participant	Baseline Mean	Intervention Mean	Test Statistic	Significance
1*	163.3°	163.4°	$t_{(74)} = -0.58$	$p > 0.05$
1†	163.7°	163.4°	$t_{(64)} = 0.216$	$p > 0.05$
2	171.2°	170.7°	$t_{(68)} = 0.534$	$p > 0.05$
3	161.1°	162.6°	$t_{(88)} = -1.489$	$p > 0.05$;
4	164.9°	161.3°	$t_{(77)} = 2.407$	$p < 0.05$;

Baseline and Intervention Means and Test Statistics for Torso Lean

Participant	Baseline Mean	Intervention Mean	Test Statistic	Significance
1*	38.1°	37.2°	$t_{(74)} = 1.078$	$p > 0.05$
1†	37.6°	37.2°	$t_{(64)} = 0.466$	$p > 0.05$
2	41.8°	41.0°	$t_{(68)} = 0.903$	$p > 0.05$
3	35.3°	35.0°	$t_{(88)} = .410$	$p > 0.05$
4	41.9°	44.6°	$t_{(77)} = .20304$	$p > 0.05$

Baseline and Intervention Means and Test Statistics for Hip Extension

Participant	Baseline Mean	Intervention Mean	Test Statistic	Significance
1*	25.4°	24.1°	$t_{(74)} = 0.681$	$p > 0.05$
1†	23.9°	24.1°	$t_{(64)} = -0.119$	$p > 0.05$
2	31.0°	29.0°	$t_{(68)} = 1.366$	$p > 0.05$
3	23.6°	24.9°	$t_{(88)} = -1.233$	$p > 0.05$
4	29.4°	24.1°	$t_{(77)} = 2.938$	$p < 0.05$

*Data from session using original intervention included in baseline data.

† Data from session using original intervention excluded.

APPENDIX D:
RAW DATA

Participant 1

	Session	Session Observation Number	Cumulative Observation Number	Condition	Angle of Initial Knee Flexion	Angle of Final Knee Extension	Angle of Torso Lean	Angle of Hip Extension
1	1.00	1.00	1.00	Baseline	98.70	172.90	41.70	33.30
2	1.00	2.00	2.00	Baseline	107.10	161.30	42.40	24.30
3	1.00	3.00	3.00	Baseline	116.50	153.60	41.50	16.80
4	1.00	4.00	4.00	Baseline	105.30	165.20	45.30	24.80
5	1.00	5.00	5.00	Baseline	111.90	163.90	36.10	16.90
6	1.00	6.00	6.00	Baseline	106.50	168.80	37.00	20.00
7	1.00	7.00	7.00	Baseline	111.20	172.10	42.10	21.20
8	1.00	8.00	8.00	Baseline	119.10	159.50	35.40	17.90
9	1.00	9.00	9.00	Baseline	107.70	160.90	36.80	33.30
10	1.00	10.00	10.00	Baseline	117.60	165.80	33.50	25.20
11	2.00	1.00	11.00	Baseline	101.50	168.40	37.40	29.90
12	2.00	2.00	12.00	Baseline	112.30	158.80	39.20	24.50
13	2.00	3.00	13.00	Baseline	107.40	162.80	41.40	23.00
14	2.00	4.00	14.00	Baseline	111.00	165.60	38.00	29.80
15	2.00	5.00	15.00	Baseline	126.20	161.70	29.00	21.80
16	2.00	6.00	16.00	Baseline	110.80	155.90	35.20	12.60
17	2.00	7.00	17.00	Baseline	116.70	161.40	36.10	26.60
18	2.00	8.00	18.00	Baseline	101.50	177.70	35.50	41.20
19	2.00	9.00	19.00	Baseline	116.00	154.00	30.10	12.20
20	2.00	10.00	20.00	Baseline	100.50	163.50	39.10	22.40
21	3.00	1.00	21.00	Baseline	107.90	159.10	42.30	29.30
22	3.00	2.00	22.00	Baseline	111.90	151.70	41.00	22.80
23	3.00	3.00	23.00	Baseline	106.40	164.50	38.80	30.50
24	3.00	4.00	24.00	Baseline	105.90	159.50	39.10	29.10
25	3.00	5.00	25.00	Baseline	109.60	163.10	37.50	24.70
26	3.00	6.00	26.00	Baseline	104.20	167.20	35.70	30.20
27	3.00	7.00	27.00	Baseline	114.70	163.40	38.20	32.60
28	3.00	8.00	28.00	Baseline	109.10	161.70	40.30	26.00
29	3.00	9.00	29.00	Baseline	110.20	165.80	39.40	31.60

30	3.00	10.00	30.00	Baseline	108.10	168.50	36.80	26.50
31	4.00	1.00	31.00	Intervention	104.00	157.90	37.60	29.20
32	4.00	2.00	32.00	Intervention	98.20	164.40	24.60	28.90
33	4.00	3.00	33.00	Intervention	107.90	166.20	35.50	32.60
34	4.00	4.00	34.00	Intervention	95.50	159.60	39.10	23.50
35	4.00	5.00	35.00	Intervention	99.20	999.00	999.00	999.00
36	4.00	6.00	36.00	Intervention	999.00	170.50	33.10	33.60
37	4.00	7.00	37.00	Intervention	106.40	166.20	33.30	40.30
38	4.00	8.00	38.00	Intervention	93.90	173.90	36.20	35.50
39	4.00	9.00	39.00	Intervention	101.90	999.00	999.00	999.00
40	4.00	10.00	40.00	Intervention	95.30	168.50	36.70	39.40
41	5.00	1.00	41.00	Intervention	92.20	168.70	36.40	23.30
42	5.00	2.00	42.00	Intervention	90.60	156.70	37.50	22.50
43	5.00	3.00	43.00	Intervention	999.00	999.00	999.00	999.00
44	5.00	4.00	44.00	Intervention	88.60	160.90	40.30	26.90
45	5.00	5.00	45.00	Intervention	92.00	166.20	34.30	25.00
46	5.00	6.00	46.00	Intervention	94.80	156.00	37.00	24.00
47	5.00	7.00	47.00	Intervention	93.30	163.40	38.40	20.40
48	5.00	8.00	48.00	Intervention	95.50	164.40	40.20	22.20
49	5.00	9.00	49.00	Intervention	92.40	163.90	37.00	24.30
50	5.00	10.00	50.00	Intervention	96.50	168.90	34.70	14.90
51	6.00	1.00	51.00	Intervention	90.00	153.30	37.50	15.30
52	6.00	2.00	52.00	Intervention	92.70	155.50	38.50	5.50
53	6.00	3.00	53.00	Intervention	92.10	164.90	39.70	13.50
54	6.00	4.00	54.00	Intervention	90.90	153.90	45.40	13.00
55	6.00	5.00	55.00	Intervention	102.90	160.60	33.70	17.60
56	6.00	6.00	56.00	Intervention	94.70	163.40	38.80	25.30
57	6.00	7.00	57.00	Intervention	999.00	999.00	999.00	999.00
58	6.00	8.00	58.00	Intervention	91.10	169.70	36.80	34.20
59	6.00	9.00	59.00	Intervention	93.80	164.70	42.70	28.70
60	6.00	10.00	60.00	Intervention	86.80	158.60	38.00	19.00
61	7.00	1.00	61.00	Intervention	95.30	165.70	39.50	33.30
62	7.00	2.00	62.00	Intervention	93.80	156.90	43.70	17.80
63	7.00	3.00	63.00	Intervention	92.50	163.40	35.90	21.20

64	7.00	4.00	64.00	Intervention	92.30	162.30	35.00	28.50
65	7.00	5.00	65.00	Intervention	91.20	170.20	34.30	30.90
66	7.00	6.00	66.00	Intervention	97.60	151.40	39.10	12.00
67	7.00	7.00	67.00	Intervention	91.00	170.50	40.10	25.70
68	7.00	8.00	68.00	Intervention	92.80	171.40	37.70	34.20
69	7.00	9.00	69.00	Intervention	90.00	170.10	36.80	35.00
70	7.00	10.00	70.00	Intervention	90.60	160.20	37.00	22.60
71	8.00	1.00	71.00	Intervention	88.80	165.20	40.00	24.50
72	8.00	2.00	72.00	Intervention	93.20	155.00	40.00	14.30
73	8.00	3.00	73.00	Intervention	91.60	167.30	32.90	26.00
74	8.00	4.00	74.00	Intervention	99.00	154.90	43.00	6.00
75	8.00	5.00	75.00	Intervention	90.50	169.50	36.60	30.10
76	8.00	6.00	76.00	Intervention	93.30	159.30	35.30	14.40
77	8.00	7.00	77.00	Intervention	91.70	166.80	35.40	23.10
78	8.00	8.00	78.00	Intervention	96.60	160.30	36.10	12.70
79	8.00	9.00	79.00	Intervention	90.20	165.70	34.50	32.50
80	8.00	10.00	80.00	Intervention	91.90	167.30	34.70	27.10
Total N	80	80	80	80	77	76	76	76

Participant 2

	Session	Session Observation Number	Cumulative Observation Number	Condition	Angle of Initial Knee Flexion	Angle of Final Knee Extension	Angle of Torso Lean	Angle of Hip Extension
1	1.00	1.00	1.00	Baseline	104.00	170.70	40.00	19.70
2	1.00	2.00	2.00	Baseline	106.90	171.70	42.20	31.70
3	1.00	3.00	3.00	Baseline	114.00	172.50	40.50	30.40
4	1.00	4.00	4.00	Baseline	107.10	171.70	37.00	34.40
5	1.00	5.00	5.00	Baseline	107.70	173.80	41.20	30.70
6	1.00	6.00	6.00	Baseline	104.30	168.80	44.80	29.80
7	1.00	7.00	7.00	Baseline	105.60	170.20	37.00	33.60
8	1.00	8.00	8.00	Baseline	99.20	166.90	38.50	27.10
9	1.00	9.00	9.00	Baseline	116.70	176.40	41.00	35.10
10	1.00	10.00	10.00	Baseline	107.80	164.80	45.10	28.50
11	2.00	1.00	11.00	Baseline	114.50	176.20	39.60	37.70
12	2.00	2.00	12.00	Baseline	107.30	169.80	42.60	35.60
13	2.00	3.00	13.00	Baseline	107.20	174.90	39.50	35.10
14	2.00	4.00	14.00	Baseline	105.00	172.20	40.20	28.40
15	2.00	5.00	15.00	Baseline	105.90	168.90	42.40	29.00
16	2.00	6.00	16.00	Baseline	105.20	176.20	39.60	32.80
17	2.00	7.00	17.00	Baseline	110.70	171.20	44.30	35.40
18	2.00	8.00	18.00	Baseline	109.00	171.90	40.30	29.40
19	2.00	9.00	19.00	Baseline	100.90	171.40	42.30	35.90
20	2.00	10.00	20.00	Baseline	109.90	171.00	41.90	35.20
21	3.00	1.00	21.00	Baseline	113.20	169.20	48.80	24.20
22	3.00	2.00	22.00	Baseline	106.50	165.50	43.40	20.10
23	3.00	3.00	23.00	Baseline	104.70	168.70	43.10	30.40
24	3.00	4.00	24.00	Baseline	112.00	173.80	42.20	36.80
25	3.00	5.00	25.00	Baseline	107.20	164.90	35.30	25.90
26	3.00	6.00	26.00	Baseline	112.70	175.00	42.80	38.20
27	3.00	7.00	27.00	Baseline	107.00	172.20	40.90	33.80
28	3.00	8.00	28.00	Baseline	102.70	174.10	42.70	30.60
29	3.00	9.00	29.00	Baseline	104.30	173.20	46.40	32.40

30	3.00	10.00	30.00	Baseline	110.20	169.20	48.20	22.90
31	4.00	1.00	31.00	Intervention	108.90	177.20	36.60	19.50
32	4.00	2.00	32.00	Intervention	104.40	170.20	36.20	24.60
33	4.00	3.00	33.00	Intervention	103.50	170.30	43.70	23.40
34	4.00	4.00	34.00	Intervention	107.00	161.70	42.90	19.10
35	4.00	5.00	35.00	Intervention	110.70	170.10	37.80	29.30
36	4.00	6.00	36.00	Intervention	102.60	165.90	39.80	27.40
37	4.00	7.00	37.00	Intervention	106.40	165.60	34.30	25.90
38	4.00	8.00	38.00	Intervention	99.90	167.80	35.40	27.50
39	4.00	9.00	39.00	Intervention	110.00	170.30	36.20	26.70
40	4.00	10.00	40.00	Intervention	105.90	168.50	35.20	21.50
41	5.00	1.00	41.00	Intervention	99.30	170.40	43.90	36.80
42	5.00	2.00	42.00	Intervention	101.70	164.10	39.20	30.70
43	5.00	3.00	43.00	Intervention	103.60	170.40	39.30	36.30
44	5.00	4.00	44.00	Intervention	102.10	175.40	37.20	24.30
45	5.00	5.00	45.00	Intervention	97.70	159.40	34.50	10.70
46	5.00	6.00	46.00	Intervention	100.80	172.20	35.90	25.10
47	5.00	7.00	47.00	Intervention	102.60	166.00	43.90	38.10
48	5.00	8.00	48.00	Intervention	103.20	177.00	42.10	33.10
49	5.00	9.00	49.00	Intervention	103.10	172.20	40.60	40.20
50	5.00	10.00	50.00	Intervention	101.20	173.80	37.30	33.00
51	6.00	1.00	51.00	Intervention	102.50	174.70	48.50	28.60
52	6.00	2.00	52.00	Intervention	100.40	164.50	41.20	19.30
53	6.00	3.00	53.00	Intervention	103.10	171.70	41.90	25.60
54	6.00	4.00	54.00	Intervention	97.30	163.90	51.80	31.00
55	6.00	5.00	55.00	Intervention	101.70	173.20	42.30	26.30
56	6.00	6.00	56.00	Intervention	99.30	166.30	47.10	19.70
57	6.00	7.00	57.00	Intervention	99.40	165.70	37.90	23.20
58	6.00	8.00	58.00	Intervention	104.80	173.60	43.70	39.70
59	6.00	9.00	59.00	Intervention	97.70	175.90	36.30	32.30
60	6.00	10.00	60.00	Intervention	103.00	177.50	41.00	37.20
61	7.00	1.00	61.00	Intervention	103.90	173.20	45.00	34.00
62	7.00	2.00	62.00	Intervention	101.80	167.70	43.10	19.00
63	7.00	3.00	63.00	Intervention	100.80	176.20	45.50	30.80

64	7.00	4.00	64.00	Intervention	97.10	174.90	45.20	35.20
65	7.00	5.00	65.00	Intervention	105.20	173.40	39.90	38.10
66	7.00	6.00	66.00	Intervention	97.00	174.50	40.70	31.10
67	7.00	7.00	67.00	Intervention	100.80	172.00	42.80	32.40
68	7.00	8.00	68.00	Intervention	99.60	171.50	41.40	32.60
69	7.00	9.00	69.00	Intervention	97.00	180.00	47.60	40.20
70	7.00	10.00	70.00	Intervention	95.20	169.10	44.10	30.30
Total N	70	70	70	70	70	70	70	70

Participant 3

	Session	Session Observation Number	Cumulative Observation Number	Condition	Angle of Initial Knee Flexion	Angle of Final Knee Extension	Angle of Torso Lean	Angle of Hip Extension
1	1.00	1.00	1.00	Baseline	104.30	147.30	41.60	19.80
2	1.00	2.00	2.00	Baseline	106.40	169.20	39.00	19.90
3	1.00	3.00	3.00	Baseline	109.00	158.70	33.30	24.90
4	1.00	4.00	4.00	Baseline	109.60	160.30	40.60	20.10
5	1.00	5.00	5.00	Baseline	105.40	158.20	35.60	21.40
6	1.00	6.00	6.00	Baseline	104.10	157.90	34.00	18.10
7	1.00	7.00	7.00	Baseline	103.50	161.90	35.00	20.50
8	1.00	8.00	8.00	Baseline	109.70	156.70	35.40	20.70
9	1.00	9.00	9.00	Baseline	112.90	161.10	33.60	26.80
10	1.00	10.00	10.00	Baseline	107.90	168.70	29.50	38.90
11	2.00	1.00	11.00	Baseline	111.90	160.80	34.80	29.00
12	2.00	2.00	12.00	Baseline	108.40	154.80	37.00	21.70
13	2.00	3.00	13.00	Baseline	108.60	160.40	36.50	21.70
14	2.00	4.00	14.00	Baseline	102.90	163.70	34.20	26.90
15	2.00	5.00	15.00	Baseline	115.40	170.80	33.60	29.90
16	2.00	6.00	16.00	Baseline	107.50	157.80	33.00	24.50
17	2.00	7.00	17.00	Baseline	103.20	163.60	34.50	23.60
18	2.00	8.00	18.00	Baseline	107.60	165.50	42.30	26.50
19	2.00	9.00	19.00	Baseline	107.20	160.80	33.20	28.10
20	2.00	10.00	20.00	Baseline	106.70	167.40	34.50	28.20
21	3.00	1.00	21.00	Baseline	102.50	157.60	36.50	22.70
22	3.00	2.00	22.00	Baseline	105.00	155.00	41.80	27.30
23	3.00	3.00	23.00	Baseline	108.80	164.10	38.60	23.80
24	3.00	4.00	24.00	Baseline	102.80	164.20	32.00	22.50
25	3.00	5.00	25.00	Baseline	102.60	163.30	37.40	27.70
26	3.00	6.00	26.00	Baseline	106.10	163.10	35.90	23.90
27	3.00	7.00	27.00	Baseline	106.40	168.60	32.40	22.20
28	3.00	8.00	28.00	Baseline	101.60	167.00	35.00	31.20

29	3.00	9.00	29.00	Baseline	102.80	170.00	34.10	25.10
30	3.00	10.00	30.00	Baseline	109.90	164.70	32.50	21.70
31	4.00	1.00	31.00	Baseline	105.10	155.80	36.00	25.50
32	4.00	2.00	32.00	Baseline	106.30	156.10	38.20	12.50
33	4.00	3.00	33.00	Baseline	108.00	159.20	33.80	25.10
34	4.00	4.00	34.00	Baseline	108.50	161.40	35.40	27.20
35	4.00	5.00	35.00	Baseline	106.40	154.60	33.90	20.30
36	4.00	6.00	36.00	Baseline	101.30	158.60	32.70	20.80
37	4.00	7.00	37.00	Baseline	102.90	155.40	39.10	15.80
38	4.00	8.00	38.00	Baseline	103.40	159.20	29.30	16.70
39	4.00	9.00	39.00	Baseline	108.00	161.10	33.60	21.60
40	4.00	10.00	40.00	Baseline	102.40	160.10	33.70	19.20
41	5.00	1.00	41.00	Intervention	117.20	163.50	38.20	26.30
42	5.00	2.00	42.00	Intervention	103.70	152.40	33.70	22.50
43	5.00	3.00	43.00	Intervention	110.90	159.30	38.40	27.40
44	5.00	4.00	44.00	Intervention	98.40	159.50	33.00	24.40
45	5.00	5.00	45.00	Intervention	104.00	165.00	35.60	34.60
46	5.00	6.00	46.00	Intervention	101.90	158.40	34.30	26.40
47	5.00	7.00	47.00	Intervention	115.20	161.70	33.60	26.70
48	5.00	8.00	48.00	Intervention	101.90	161.50	35.00	24.50
49	5.00	9.00	49.00	Intervention	117.20	168.70	28.30	30.40
50	5.00	10.00	50.00	Intervention	95.00	158.40	29.20	25.00
51	6.00	1.00	51.00	Intervention	100.00	160.40	31.20	26.70
52	6.00	2.00	52.00	Intervention	101.00	161.50	33.00	31.40
53	6.00	3.00	53.00	Intervention	100.80	166.50	31.00	30.80
54	6.00	4.00	54.00	Intervention	101.20	163.10	42.70	25.90
55	6.00	5.00	55.00	Intervention	100.90	158.50	44.60	30.60
56	6.00	6.00	56.00	Intervention	99.50	163.30	36.20	30.20
57	6.00	7.00	57.00	Intervention	98.60	164.80	36.30	28.20
58	6.00	8.00	58.00	Intervention	100.20	163.90	33.00	28.70
59	6.00	9.00	59.00	Intervention	104.70	163.40	39.90	21.70
60	6.00	10.00	60.00	Intervention	98.80	161.10	34.00	23.60
61	7.00	1.00	61.00	Intervention	97.50	161.30	35.50	26.00
62	7.00	2.00	62.00	Intervention	97.10	167.70	37.90	26.80

63	7.00	3.00	63.00	Intervention	101.60	165.40	37.10	23.90
64	7.00	4.00	64.00	Intervention	100.90	172.30	35.10	32.10
65	7.00	5.00	65.00	Intervention	99.00	166.00	39.20	19.90
66	7.00	6.00	66.00	Intervention	97.70	165.20	36.30	28.90
67	7.00	7.00	67.00	Intervention	102.60	165.30	38.10	22.10
68	7.00	8.00	68.00	Intervention	104.60	163.50	31.60	24.70
69	7.00	9.00	69.00	Intervention	96.00	170.30	35.40	28.30
70	7.00	10.00	70.00	Intervention	102.60	174.40	37.90	29.00
71	8.00	1.00	71.00	Intervention	99.80	159.90	33.20	20.60
72	8.00	2.00	72.00	Intervention	102.00	158.70	30.00	25.80
73	8.00	3.00	73.00	Intervention	95.70	160.30	36.20	24.50
74	8.00	4.00	74.00	Intervention	101.20	159.10	34.60	15.90
75	8.00	5.00	75.00	Intervention	100.20	161.10	35.60	28.30
76	8.00	6.00	76.00	Intervention	90.30	161.90	33.10	22.60
77	8.00	7.00	77.00	Intervention	100.70	164.60	36.70	22.50
78	8.00	8.00	78.00	Intervention	104.20	156.30	44.60	6.10
79	8.00	9.00	79.00	Intervention	100.00	163.60	23.20	32.20
80	8.00	10.00	80.00	Intervention	98.70	159.60	28.90	18.30
81	9.00	1.00	81.00	Intervention	97.50	157.60	39.20	19.40
82	9.00	2.00	82.00	Intervention	96.20	160.40	32.90	19.40
83	9.00	3.00	83.00	Intervention	96.10	160.30	37.40	20.30
84	9.00	4.00	84.00	Intervention	95.70	153.10	35.60	17.10
85	9.00	5.00	85.00	Intervention	99.10	160.70	32.00	14.00
86	9.00	6.00	86.00	Intervention	96.60	163.30	33.30	26.60
87	9.00	7.00	87.00	Intervention	95.60	167.10	35.20	26.40
88	9.00	8.00	88.00	Intervention	99.70	162.50	31.10	19.60
89	9.00	9.00	89.00	Intervention	94.90	166.30	33.40	29.60
90	9.00	10.00	90.00	Intervention	100.30	165.70	39.30	29.00
Total N	90	90	90	90	90	90	90	90

Participant 4

	Session	Session Observation Number	Cumulative Observation Number	Condition	Angle of Initial Knee Flexion	Angle of Final Knee Extension	Angle of Torso Lean	Angle of Hip Extension
1	1.00	1.00	1.00	Baseline	109.30	153.80	38.20	27.10
2	1.00	2.00	2.00	Baseline	94.50	158.20	40.00	23.60
3	1.00	3.00	3.00	Baseline	104.80	162.90	44.40	19.40
4	1.00	4.00	4.00	Baseline	107.30	165.40	41.20	34.10
5	1.00	5.00	5.00	Baseline	106.40	165.10	41.00	32.10
6	1.00	6.00	6.00	Baseline	103.50	164.90	42.30	35.10
7	1.00	7.00	7.00	Baseline	105.30	164.10	40.50	35.40
8	1.00	8.00	8.00	Baseline	106.90	169.30	44.00	31.50
9	1.00	9.00	9.00	Baseline	109.30	171.50	43.40	36.30
10	1.00	10.00	10.00	Baseline	102.30	164.40	38.20	27.60
11	2.00	1.00	11.00	Baseline	115.20	174.50	44.80	40.90
12	2.00	2.00	12.00	Baseline	104.20	173.60	44.50	44.50
13	2.00	3.00	13.00	Baseline	104.50	175.20	46.30	30.00
14	2.00	4.00	14.00	Baseline	108.90	170.10	45.10	40.80
15	2.00	5.00	15.00	Baseline	102.60	171.00	42.10	42.00
16	2.00	6.00	16.00	Baseline	107.40	172.10	51.10	36.70
17	2.00	7.00	17.00	Baseline	107.40	175.50	48.50	36.50
18	2.00	8.00	18.00	Baseline	112.10	156.40	40.40	17.80
19	2.00	9.00	19.00	Baseline	100.60	157.60	42.40	33.20
20	2.00	10.00	20.00	Baseline	113.30	172.20	47.00	34.50
21	3.00	1.00	21.00	Baseline	107.50	164.00	44.20	28.20
22	3.00	2.00	22.00	Baseline	107.20	172.20	41.50	31.90
23	3.00	3.00	23.00	Baseline	106.80	166.50	42.00	32.40
24	3.00	4.00	24.00	Baseline	105.20	169.80	44.60	34.90
25	3.00	5.00	25.00	Baseline	111.80	170.30	51.90	32.30
26	3.00	6.00	26.00	Baseline	102.50	167.50	43.10	33.10
27	3.00	7.00	27.00	Baseline	107.50	160.70	43.00	23.40
28	3.00	8.00	28.00	Baseline	104.30	171.00	43.40	39.70
29	3.00	9.00	29.00	Baseline	108.30	172.40	44.80	37.90

30	3.00	10.00	30.00	Baseline	104.00	166.40	45.50	24.80
31	4.00	1.00	31.00	Baseline	107.80	164.60	32.10	25.70
32	4.00	2.00	32.00	Baseline	105.00	162.80	33.40	23.50
33	4.00	3.00	33.00	Baseline	99.70	163.50	35.60	21.80
34	4.00	4.00	34.00	Baseline	100.00	154.90	40.00	24.30
35	4.00	5.00	35.00	Baseline	105.50	156.90	33.50	22.10
36	4.00	6.00	36.00	Baseline	98.00	153.70	38.90	21.90
37	4.00	7.00	37.00	Baseline	105.40	163.80	36.70	31.60
38	4.00	8.00	38.00	Baseline	98.50	155.60	42.30	8.00
39	4.00	9.00	39.00	Baseline	99.90	162.10	39.40	31.00
40	4.00	10.00	40.00	Baseline	102.40	173.10	39.40	40.60
41	5.00	1.00	41.00	Baseline	95.20	156.40	39.30	22.10
42	5.00	2.00	42.00	Baseline	99.80	160.00	42.10	19.80
43	5.00	3.00	43.00	Baseline	95.60	158.60	42.60	19.10
44	5.00	4.00	44.00	Baseline	101.20	162.40	43.00	27.80
45	5.00	5.00	45.00	Baseline	111.70	168.30	42.10	28.80
46	5.00	6.00	46.00	Baseline	98.80	162.50	41.30	23.90
47	5.00	7.00	47.00	Baseline	104.20	164.40	39.50	30.70
48	5.00	8.00	48.00	Baseline	98.20	166.70	44.00	32.70
49	5.00	9.00	49.00	Baseline	105.00	162.00	38.30	20.30
50	5.00	10.00	50.00	Baseline	102.80	154.50	42.90	15.40
51	6.00	1.00	51.00	Intervention	98.10	161.30	36.80	30.60
52	6.00	2.00	52.00	Intervention	92.50	175.60	33.50	29.60
53	6.00	3.00	53.00	Intervention	93.10	168.40	41.20	32.60
54	6.00	4.00	54.00	Intervention	92.10	163.00	40.60	18.60
55	6.00	5.00	55.00	Intervention	100.30	161.30	38.40	29.20
56	6.00	6.00	56.00	Intervention	96.80	175.70	37.60	27.40
57	6.00	7.00	57.00	Intervention	96.90	162.20	39.30	30.70
58	6.00	8.00	58.00	Intervention	90.20	163.70	34.10	31.60
59	6.00	9.00	59.00	Intervention	93.30	158.70	37.30	20.60
60	6.00	10.00	60.00	Intervention	94.20	166.60	36.20	37.10
61	7.00	1.00	61.00	Intervention	93.70	170.10	37.20	33.10
62	7.00	2.00	62.00	Intervention	95.00	165.30	46.50	35.80
63	7.00	3.00	63.00	Intervention	89.50	999.00	999.00	999.00

64	7.00	4.00	64.00	Intervention	90.00	164.50	46.30	30.10
65	7.00	5.00	65.00	Intervention	91.90	164.40	45.40	25.30
66	7.00	6.00	66.00	Intervention	90.00	166.70	45.60	24.30
67	7.00	7.00	67.00	Intervention	91.20	154.80	44.10	29.10
68	7.00	8.00	68.00	Intervention	92.80	157.50	48.60	20.40
69	7.00	9.00	69.00	Intervention	97.50	156.50	49.80	10.50
70	7.00	10.00	70.00	Intervention	94.70	152.60	55.30	22.00
71	8.00	1.00	71.00	Intervention	95.90	162.60	52.40	18.60
72	8.00	2.00	72.00	Intervention	90.00	160.70	54.30	22.60
73	8.00	3.00	73.00	Intervention	90.20	160.80	47.90	21.30
74	8.00	4.00	74.00	Intervention	89.30	158.00	52.60	23.40
75	8.00	5.00	75.00	Intervention	98.40	151.80	51.00	13.20
76	8.00	6.00	76.00	Intervention	97.40	152.20	52.20	15.40
77	8.00	7.00	77.00	Intervention	93.60	146.40	45.00	14.50
78	8.00	8.00	78.00	Intervention	87.40	160.30	51.60	27.10
79	8.00	9.00	79.00	Intervention	93.60	159.20	45.60	10.00
80	8.00	10.00	80.00	Intervention	95.50	157.80	47.00	14.60
Total N	80	80	80	80	80	79	79	79