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THE EFFECT OF A PASSIVE OR ACTIVE RECOVERY ON BOWLING

SPEED DURING A TEN OVER SPELL

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GLOSSARY OF CRICKETING TERMS

Batting – Batting is defending the wicket and scoring runs.

Bowling – Bowling is the process of the bowler delivering the ball to the batsmen.

Crease – The point at which the bowler must release the ball in order to produce a legitimate delivery.

Delivery – The act of bowling the ball.

Field the ball – When the batsmen hits the ball the fielders are required to gather the ball to prevent a boundary being scored. This is called fielding the ball.

Front on action – Technical term for a bowler that looks inside the front arm and backfoot lands straight rather than parallel.

Innings – An innings constitutes one teams opportunity to bat. In the different forms of the game the length of innings will vary.

Over – Six balls delivered by one bowler make up an over

Side on action – is a technical classification for a bowler who looks outside their front arm and the back foot landing is parallel to the crease.

Spell – A spell refers to the number of overs a bowler bowls before being replaced. For example five overs, would be a five over spell

Walking in – The concept of the fielders walking in towards the batsmen when the bowler is running in, in order to pressurise the batsmen and to be prepared to field the ball.

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LIST OF ABBREVIATIONS

°C.....	Degrees Celsius
ATP.....	Adenosine Triphosphate
Bpm ⁻¹	Beats per minute
CV.....	Cardio Vascular
HR.....	Heart Rate
HR _{max}	Heart Rate Maximum
Km/h ⁻¹	Kilometres per hour
l·h ⁻¹	Litres per hour
LT.....	Lactate Threshold
mmol·l ⁻¹	Millimoles per Litre
MAS.....	Maximal Aerobic Speed
OBLA.....	Onset of Blood Lactate Accumulation
PA.....	Power Average
PCr.....	Phosphocreatine
PO.....	Power Output
PP.....	Peak Power
Q.....	Cardiac Output
SV.....	Stroke Volume
TTE.....	Time To Exhaustion
VO ₂	Volume of Oxygen Uptake
VO _{2max}	Maximal Oxygen Uptake
WBGT.....	Wet Bulb Globe Temperature

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I would also like to thank Paul Glazier for the availability and use of equipment, which made the study run smoothly.

ABSTRACT

The current study is an analysis of the effectiveness of a passive, or an active recovery applied to the rest periods when bowling in cricket. The study measured the bowling peak speeds of six healthy male bowlers (20.9 ± 0.96 years). Two exercise protocols were prescribed consisting of a ten over spell of bowling (medium to fast paced) under differing recovery periods. One trial used a passive recovery between overs, the other used a three minute active recovery at an intensity of $55\%VO_{2max}$ between overs. Heart rate was measured throughout to maintain active recovery intensity and analyse the heart rate changes during bowling. The results show that there are no significant differences between the speeds in the two trials ($p > .05$). When using a passive recovery the last over is significantly slower than the tenth over ($p < .05$). Whereas when using an active recovery speed is significantly quicker between the first over and the fifth, sixth and seventh overs. The fatigue of speed is greater using a passive recovery ($12.78 \pm 3.63\%$) compared to active recovery ($9.72 \pm 1.80\%$) although not significantly different at the 0.05 level of significance, The key findings of the study are the suggestion that using an active recovery may maintain bowling speed to a greater level than passive recovery, however the results were not significant at the 0.05 level. this is could be linked to the greater amount of oxygen transported to the working muscles aiding the replenishment of Adenosinetriphosphate in three minutes of recovery, however further research is essential to reaffirm this suggestion.

CHAPTER I

INTRODUCTION

1.1 Introduction

Cricket is an intermittent team game which involves short repetitive bouts of intense exercise when batting and bowling. Early research into the physiological demands of cricket suggested that when bowling in test cricket the energy demands were less than that of walking at 6km/h^{-1} and playing tennis, (Fletcher, 1955). The research conducted by Fletcher is questionable though as he did not directly test the subjects and used previously gathered data so validity and reliability are questionable. A more accurate classification of cricket by Reilly, Secher, Snell and Williams (1990), states the severity of cricket as moderate with an energy expenditure of 21-33 KJ min^{-1} , also mentioning that it may be an underestimation compared to the elite players. Noakes and Durandt (2000) agree with the early predictions from Fletcher as studies have shown low levels of energy expenditure occur, with the exception of fast bowlers. This study aims to introduce an alternative method to the passive recovery commonly used in bowling and assess the demands on bowling and the influence of recovery mode on bowling speed.

1.2 Forms of the game

At International level cricket is played in three forms, the One Day game, the Test match and the twenty20. The One Day game is where two teams compete in a fifty over per innings match (consult glossary of terms). A Test match consists of two innings per side over the course of five days and the Twenty20 format is a new form of cricket which is a fast paced 20 over per

innings game. The physiological demands on bowlers in each format will fluctuate greatly, due to the restrictions placed on the number of overs a bowler can bowl. In a test match there is no limit placed on the bowler whereas in a one day international a ten over limit is enforced and the twenty20 format has a four over limit. The main aim of cricket is to score more runs than the other team. When bowling the aim is to dismiss ten batsmen, then the team is 'all out'. The two teams change roles and the team who batted first will bowl and prevent the opposition from surpassing their score. It is clear that bowlers are a key member of any cricket side, and anything to aid their performance is of great benefit to a coach and his side.

1.3 Rationale of study area

Once a bowler has completed an over there is on average three minutes and twenty seconds of recovery time before the next over (Fletcher, 1955). During this period the bowler will try to limit the amount of movement during the recovery phase to allow the body to fully recovery without increasing exertion on the physiological systems. Fletcher (1955) suggested when the bowler is fielding they are on average required to field the ball 8.1 times per hour, this shows there is relatively little physiological demands except walking to their fielding position during the rest period.

This study will focus on the activity that the bowler undertakes during this period, and how this impacts upon their bowling speed. Active recovery would involve exercise between overs to maintain blood flow, and increase heart rate (HR). Passive would involve the subjects limiting physical activity to a minimum throughout the recovery period.

The importance of speed in cricket, which supports the relevance and need for a study of this type is summed up by former England Coach Duncan Fletcher.

“Cricket is all about speed these days. Fast bowling, fast spin, and fast batting. That means the speed of the ball, bat speed and the speed of revolutions on the ball. That’s why I felt that if we had four bowlers bowling over 85mph we had a chance of winning the ashes”

(Fletcher 2006).

There are many benefits of maintaining bowling speed during a spell. “The ball release speed of a fast bowler in cricket is widely acknowledged as an important characteristic, as it can reduce the decision making and stroke execution time of the opposing batsmen” (Abernethy, 1981). If a bowler can consistently produce deliveries which are of a high speed they can gain a psychological edge, due to the relentlessness of the bowling attack. If the bowlers speed is in rapid decline the batsmen are able to “line up” the

bowler, this means they become more comfortable, have more time for shot selection and can premeditate shots. A batsmen imposing themselves on the bowler in such a way can gain a great psychological advantage and largely puts the batsmen in the acendency.

1.4 Current Research

1.4.1 Heart Rate

The ability to recover quickly is critical if bouts of all out activity are required (Tomlin and Wenger, 2001). Although bowling in cricket is not “all out” in nature, heart rates of 190bpm^{-1} have been recorded. Burnett et al (1995) discovered that bowlers operated at a range of 80.3% of their heart rate max (HR_{max}) in the first over and 84.7% of HR_{max} in the twelfth over. The increase in HR was attributed to the greater demand for oxygen in the working muscles as the body fatigues.

1.4.2 Lactate removal

Active recovery has been proven to decrease time to exhaustion (TTE) by decreasing blood lactate concentration. Many studies have been conducted to measure the effectiveness of an active and passive recovery on blood lactate concentration. There is contradictory evidence supporting both modes of recovery and is greatly dependant upon the length and intensity prescribed for both active and passive recovery periods . This can be applied

to the recovery of a bowler in cricket as in some cases blood lactate has reached $7.9\text{mmol}\cdot\text{L}^{-1}$ (Burnett et al, 1995) in fast bowlers.

1.4.3 Power Output

Active recovery can improve power output (PO) (Spencer, Bishop, Dawson, Goodman and Duffield, 2006) which can benefit the power aspect of bowling. The increased availability of oxygen to the working muscles allows for 90-95% of Adenosine Triphosphate (ATP) replenishment when the recovery period is greater than three minutes. The underlying theory of the active recovery and PO can be applied to the explosive powerful nature of bowling in cricket.

1.5 Practical uses

The results of this study may have practical uses for players and coaches with regards to training regime and on field actions. If the use of an active recovery can enhance the level of performance (speed) then the ideas explored in this study can be applied to amateur cricketers across the board, and can lead to further investigation in the field of recovery and elite fast bowlers. As there is no research done into recovery of bowlers in cricket and mode of recovery this study is unique and may lend itself to further investigation.

1.6 Conclusion

An extensive literature review shall be conducted in order to determine how the active recovery can be applied to the rest period in bowling and to what extent it may be of benefit to the performer. The research suggests that there may be an improved power performance, which may increase bowling speed. There is also research to suggest that if blood lactate levels rise then there shall be a greater rate lactate removal, however there is contradictory evidence to this.

CHAPTER III
METHODOLOGY

3.1 Subjects

Six male subjects were chosen from the University of Wales, Institute Cardiff (UWIC) cricket squad. The subjects that were chosen matched the selection criteria.

- I. Fit and in good health with no recent injuries or receiving medication
- II. A Medium to fast paced bowler (55 - 90+Mph)
- III. Must be able work high percentages of HR_{max} for the duration of over an hour
- IV. Must be twenty years and over in order to comply with the England Cricket Board (ECB) bowling regulations.

The subject's characteristics are summarised in table 2. Informed consent was acquired in writing from each subject after being informed of the protocol and possible risks of the study.

Table 2. Subject characteristics. (Mean \pm s),

Age (years)	20.9 \pm 0.96
Height (cm)	184.52 \pm 11.99
Body Mass (Kg)	80.17 \pm 12.48
Predicted HR max (bpm ⁻¹)	199.1 \pm 0.96

3.2 Pilot Study

A pilot study was conducted in advance of the trial to identify if any problems occurred during the passive recovery protocol such as HR recording or bowling speed. Data from the pilot study are summarised in appendix B. There were no problems with the protocol prescribed. The only change made to the protocol was the units of speed from km/h^{-1} to mph^{-1} . The reason for this is that it is more applicable to the cricket setting as speed in International matches in England are measured in mph^{-1} .

3.3 Warm up protocol

The warm up period is essential to all physical performance. Due to the large amount of muscles that are used during bowling a thorough warm up was completed, as it is imperative to avoid the possibility of injury and to maximise performance. The warm up provided a gradual lead up to more vigorous exercise. This process stretched the muscle-tendon unit to allow greater length and less tension when the bowling begins.

The warm up consisted of four minutes progressive jogging. The subjects kept their HR above 120bpm^{-1} . This was done to ensure that the warm up was progressive and the blood flow to the major muscles would increase, prior to stretching. The subjects then spent four minutes completing stretches both passively and dynamically. Dynamic stretching was encouraged as this type of stretching takes the muscle through the actions

that were required during the test. After eight minutes of warm up the subjects completed three practice deliveries to ensure they were fully prepared for the activity.

3.4 Protocol with passive recovery

The testing was conducted in the National Indoor Athletic Centre, Cardiff (NIAC). The humidity and temperature were measured at the beginning of each trial using a weather station (Mobile weather station, Oregon scientific). The protocol used during both passive and active recoveries replicated a real match situation with two bowlers bowling in tandem (alternating), however there was at least a three minute recovery period enforced in the situation of a bowler finishing an over quickly. The bowlers marked out their run ups and checked to make sure that the length was correct to prevent any no-balls (illegitimate) being bowled. The HR monitor was activated start of the first over and the bowler completed a six ball over using a four piece cricket ball (Davidson, India) bowling into a net with a radar gun (StalkerSPORT, Plano) situated behind to measure each ball speed (figure 1). Once the over was complete the second bowler began the study in the same fashion. When the second subject was completing their over the first subject was recovering.

The recovery period involved the subject walking in (see glossary of terms) with the bowler and retrieving the ball from the net. In order to maintain a

realistic environment the subjects had to field the ball eight times per hour as the research suggests. This was randomly assigned during the test and involved the administrator rolling a ball out 20 meters into space and the subject retrieving the ball and throwing back at set of stumps. During the test the bowlers were allowed to drink from water bottles at the end of their overs as this is permitted during cricket if a fielder is on the boundary. The subjects were allowed to stretch, but unnecessary high intensity exercise was forbidden such as short sprints. This was to maintain a realistic environment throughout. Once the ten overs were completed the HR monitor was stopped and a cool down was undertaken.

3.5 Protocol with active recovery

The protocol with an active recovery used the same warm up period as was conducted for the passive recovery protocol. Once the subjects had completed the warm up a similar protocol applied. The subjects completed a spell of ten overs while having speed and HR monitored. An active recovery was performed following the over. This was done to increase blood flow to the working muscles, to allow greater resynthesis of ATP and to enhance lactate removal. The use of an online system to calculate VO_2 could not be applied to a cricket setting therefore other means were required to calculate the active recovery intensity. As suggested by Swain *et al* (1993) a percentage of VO_2 can be predicted by using the HR_{max} value. Gisolfi *et al* (1966) suggest that optimal lactate removal occurs between 50% and 65% of VO_{2max} in trained athletes. A value of 55% HR_{max} was assigned in the current

study, this was due to the value not being too excessive to maintain, would increase blood flow in the muscles and if lactate production occurred it would be between optimal levels of removal for trained subjects. Using the method produced by Swain *et al* (1993) 55% of VO_{2max} in healthy fit males is approximately 74% HR_{max} . Using simple calculations 74% HR_{max} was calculated for each bowler, giving a HR value that they must work at during the active recovery. HR_{max} was calculated using an age related prediction $HR_{max} = 200 - \text{Age (years)}$ (McArdle *et al*, 2003).

Table 3. % HR_{max} administered during active recovery for different age groups.

Subject	74% HR_{max}
20 years	148 bpm
21 years	147.3 bpm
22 years	146.5 bpm

In order for the subject to maintain this HR short intermittent exercises were conducted between two cones set ten meters apart. The reasons for this were to allow realism, as there is only a limited amount of exercises that could be applied on the cricket field. The subjects prescribed their own active recovery exercises as certain exercises were more suitable for raising the HR and were found more comfortable to perform. The HR monitors worn by the performers were checked by the administrator to ensure the HR was at the desired intensity. Once the rest period was finished the subject immediately bowled the next over. The subjects were authorised to consume

water during the study during the recovery period. On completion of the study the subjects conducted a cool down.

3.5.1 Active recovery exercises

During the active recovery short intermittent high intensity exercises were prescribed. The subjects administered their own exercises but were monitored to ensure that no continuous exercises were undertaken. The explanation for the strict protocol was to prevent the nature of the recovery period shifting from intermittent to continuous in nature and affecting the quality of ATP resynthesis.

3.6 Protocol for accessing performance

To access performance a radar gun (StalkerSPORT, Plano) was used to measure bowling speed. The radar gun was attached to a tripod (Velbon DF-40) using a tripod mounting cradle (Stalker, Plano) and placed 3 meters behind a net. The camera was at a height of 160cm and placed directly in line with the angle of delivery (0 degrees) to eliminate any error (Figure.1). The radar gun was set up to record peak speed (mph^{-1}), which is measured within seven inches of the ball leaving the hand. For validity purposes ten percent of the average speed of the first over was calculated. The bowlers speed had to stay within this value to ensure all out effort is achieved.

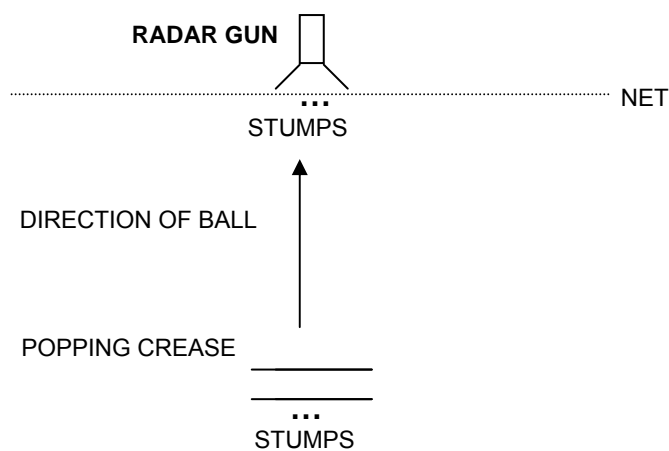


Figure 1. Equipment configuration during both protocols

3.7 Protocol for accessing Physiological measures

3.7.1 Height Protocol

Height was measured using a stadiometer (Holtain Fixed Stadiometer, Holtain LTD). The technique for measuring height adapted from MacDougall, Wenger and Green (1991) was to have the subject stand erect with the heels together, arms hanging naturally by the sides. The heels, buttocks, upper part of back and head are in contact with a vertical wall. The stadiometer was then lowered onto the vertex of the head, as the subject looked ahead and took a deep breath. The height was recorded in centimetres to the nearest tenth of a centimetre.

3.7.2 Body Mass Protocol

Body mass was measured using digital scales (SECA, Hamburg). The subject's mass was recorded with shoes removed and shorts and t-shirt being worn. The mass was measured prior to the experiment in the morning, as this is the most stable time to measure weight (MacDougall et al, 1991). Weight was recorded in Kilograms to the nearest tenth.

3.7.3 Heart Rate Monitoring Protocol

Subjects wore a (Polar S610, Finland) heart rate monitor to record HR in bpm throughout each trial. The HR monitor was set to record at five second intervals, and store the information in a file on the watch. The subjects wore a transmitter belt (Polar WearLink31, Finland) around their chests to transmit the signal to the watch. The file was uploaded from the watch (Polar Infrared USB Interface, Finland) to allow for data analysis.

3.8 Statistical Analysis

Data was collected during the two trials using a laptop computer (Acer Aspire 2002LC, Plymouth) and recorded on spreadsheets using Excel (Microsoft). Descriptive statistics have been used to describe the physiological and

speed data collected during the study. The mean accompanied by standard deviation and medians were calculated. The mean gives a measure of central tendency and gives weight to each score according to its relative distance from over scores (Vincent, 1999). The median was calculated as this does not take into account any outlying data and will provide a representation of the typical which best represented the data set. Fatigue index was also calculated by adapting a formula from the Wingate cycle ergometer test (McArdle *et al*, 2001). By adapting the anaerobic fatigue calculation the percentage decline in bowling speed could be identified.

Fatigue Index =

$(\text{Highest Peak Speed} - \text{Lowest Peak Speed}) \div \text{Highest Peak Speed} \times 100$

Data was then tested for significant differences using statistics software (SPSS v 16.0). A repeated measures one-way analysis of variance (ANOVA) test was conducted to identify if any significant differences occurred between the spells of bowling. A series of paired *t* tests were conducted to identify if any significant differences occurred during the two trials. The same test was also applied to identify significant differences in the fatigue index of the two trials. A statistical significance of 0.95 was set on all tests.

CHAPTER IV
RESULTS

4.1 Physiological Data

4.1.1 Heart rate Data

Table 4. Heart rate data from the (mean \pm Standard deviation) study including conditions of each test

	Passive recovery	Active recovery
Average HR (bpm^{-1})	147.9 \pm 17.8	150 \pm 12.2
Median (bpm^{-1})	152.1	150.3
% of Maximum HR	73.4%	75.4%
Average Maximum HR	175.5 \pm 14.3	174.2 \pm 14.01
Average Minimum HR	110.3 \pm 11.9	120.8 \pm 13.6
Average Humidity	42 \pm 4	44 \pm 4.4
Average Temperature($^{\circ}\text{C}$)	16.5 \pm 1.5	16.2 \pm 0.4

The HR data in table 4 shows that when using a passive recovery average HR was less than active recovery, however the HR during active recovery was more concentrated about the mean as suggested by the smaller standard deviation, so the active recovery period appears to administered well. The average HR_{max} was greater using passive recovery. This is related to the large standard deviation of average HR, and shows that in short bursts a greater HR was achieved using a passive recovery.

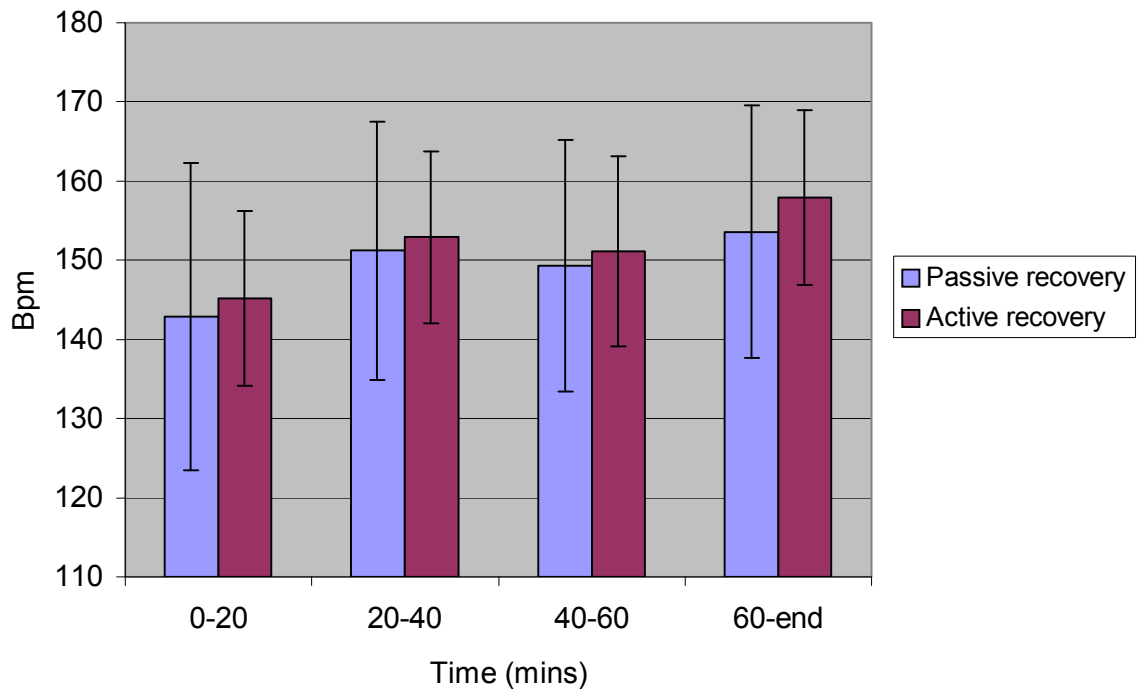


Figure 2. Average heart rate in twenty-minute intervals for passive and active recovery

In figure 2 the HR data was grouped into twenty-minute intervals to identify the changes each twenty minutes, which is approximately three and a half overs. The chart shows that at each interval the average HR was greater for active recovery, and the standard deviation was also less at each stage than that of passive recovery. The average HR decreased for both variables from 20-40mins to 40-60mins then peaked from one hour into the spell until the finish of the spell. During active recovery the mean HR increased from $145.2 \pm 11.0 \text{ bpm}^{-1}$ in the first twenty minutes to $157.9 \pm 11.0 \text{ bpm}^{-1}$ from an hour into the spell to the finish. Whereas when using passive recovery was used the HR increased from $142.9 \pm 19.4 \text{ bpm}^{-1}$ to $153.6 \pm 16.0 \text{ bpm}^{-1}$ during the same time span.

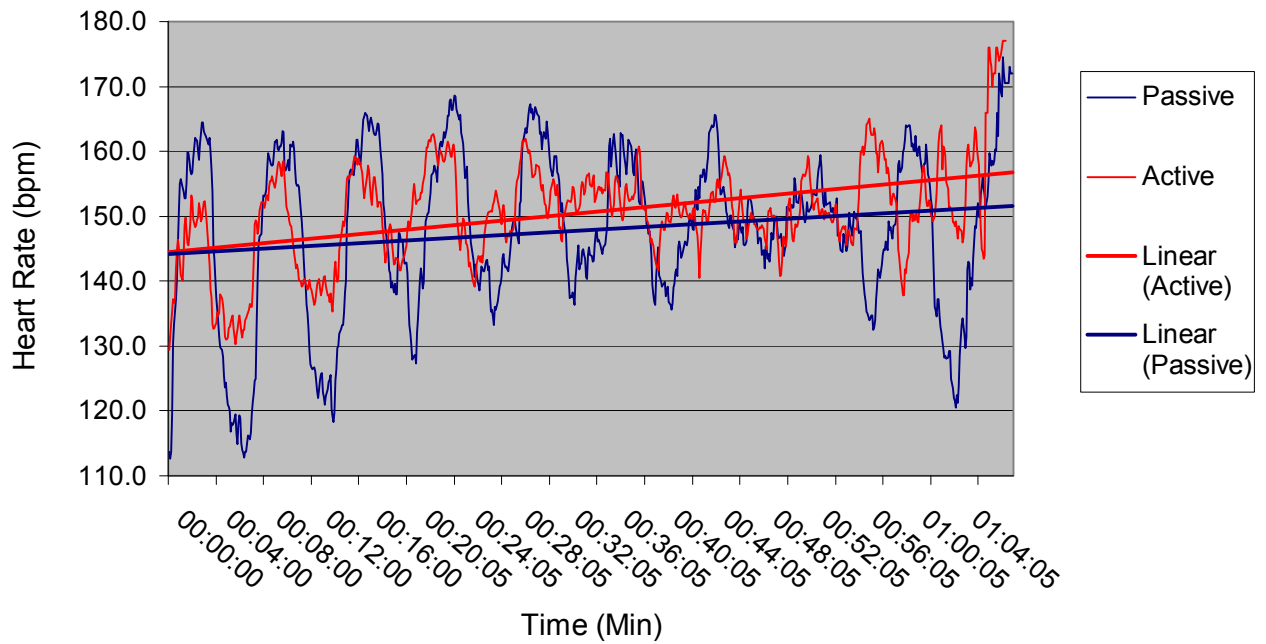


Figure 3. Average heart rate trace for passive and active recovery during the test

A HR trace was compiled containing all of the subject's heart rates over the two trials. The treadline shows that the subjects began at the same relative HR and both progressively increased. The active spell increased HR greater than the passive recovery. The active recovery line is more centred about the mean, thus the low standard deviation. The passive recovery displays more peaks and greater troughs, which suggest a lower HR during recovery and a greater HR during bowling. From figure 3 it can be seen that when using an active recovery the bowlers work at a higher HR during ten overs then using a passive recovery.

4.1.2 Fatigue Index data

Fatigue index was calculated for the each spell of bowling. When using a passive recovery the bowlers fatigue index was $12.78 \pm 3.63\%$ whereas when using an active recovery the bowlers fatigue index was only $9.72 \pm 1.80\%$. This result occurred even though when using passive recovery the bowlers worked at a lower percentage of HR_{max} (73.4%) when compared to active recovery (75.4%). A paired t test revealed that there is no significant difference in the fatigue index when doing a passive or an active recovery ($P > .05$).

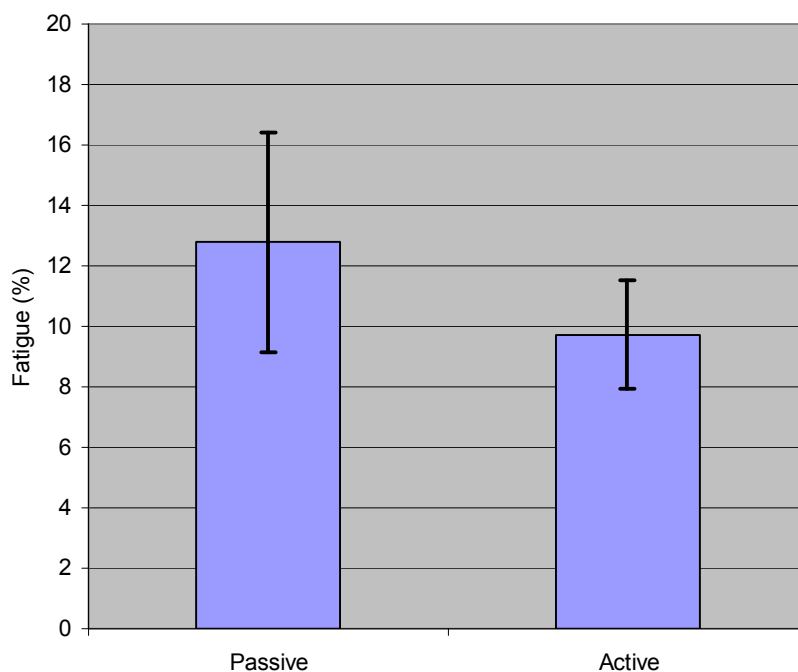


Figure 4. Fatigue index from passive and active recovery during a ten over spell

4.2 Performance data

Box-whisker diagrams can be used to assess if distribution is symmetrical or skewed (Field, 2005). The box-whisker plot for passive recovery is slightly skewed, however the active recovery displays a symmetrical distribution. There is no outlying data, which would be illustrated by a circle outside of the box plot. This shows the similarities in the data collected.

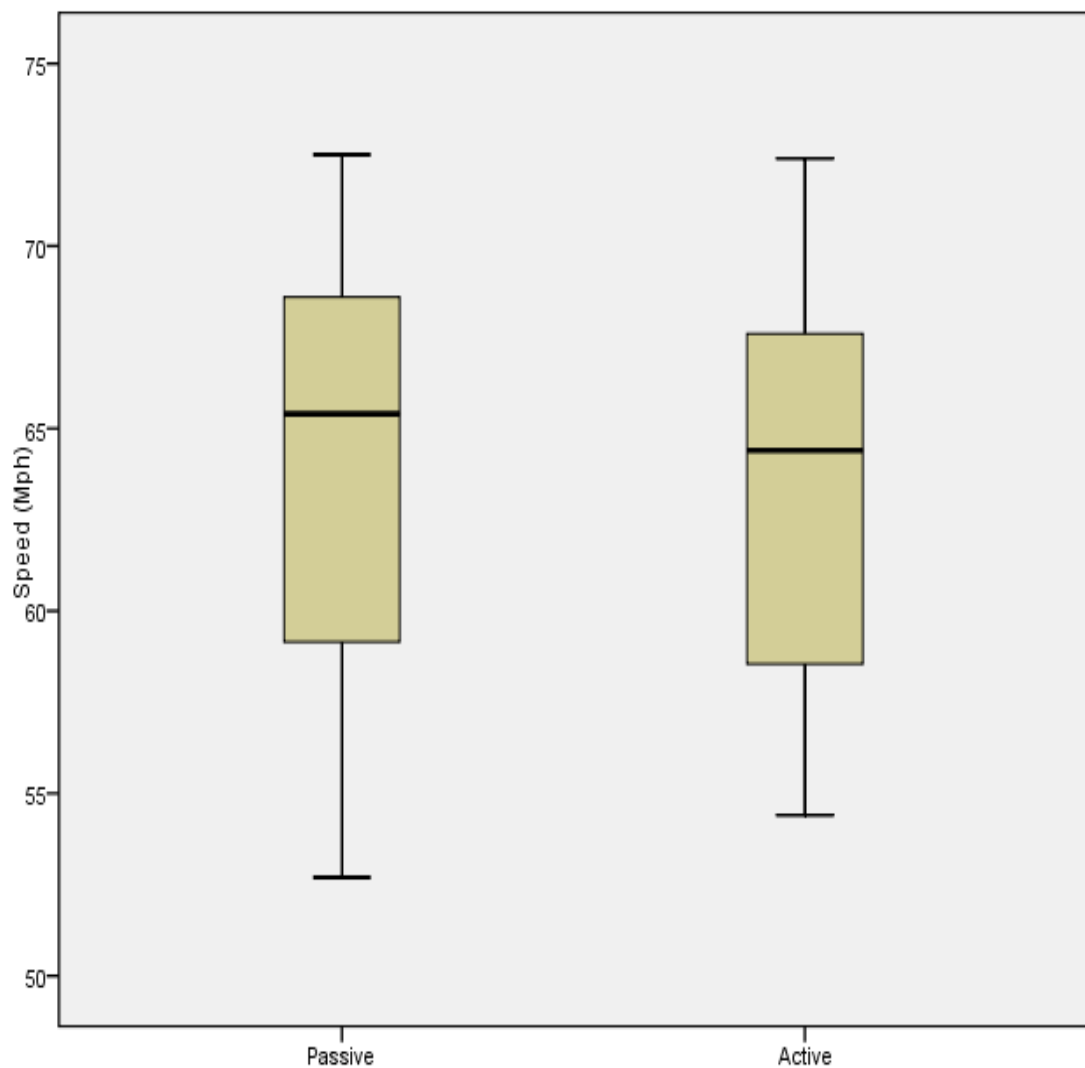


Figure 5. Box-whisker diagram of bowling speeds during the spells

4.2.1 Passive Recovery

During the passive recovery bowling spell the greatest average speed occurred in the second over $65.09 \pm 4.99 \text{ Mph}^{-1}$, and slowest speed was located in the tenth over $62.37 \pm 5.39 \text{ Mph}^{-1}$, this was at an average HR of $147.9 \pm 17.8 \text{ bpm}^{-1}$. As the spell progress the standard deviation of ball speed increases from 4.67 to 4.91 in the seventh and 5.39 in the tenth over, this suggests a greater variability in bowling speed.

4.2.2 Active Recovery

During the active recovery bowling spell the greatest average speed occurred in the fourth over $64.31 \pm 5.01 \text{ Mph}^{-1}$, and the slowest average bowling speed was in the first over $62.58 \pm 4.30 \text{ Mph}^{-1}$. There was little deviation from the mean during the spell, which suggests consistency in bowling speed throughout the spell as can be seen in figure 6. These speeds were achieved at an average HR of $150 \pm 12.2 \text{ bpm}^{-1}$, which is a greater mean HR then using passive recovery.

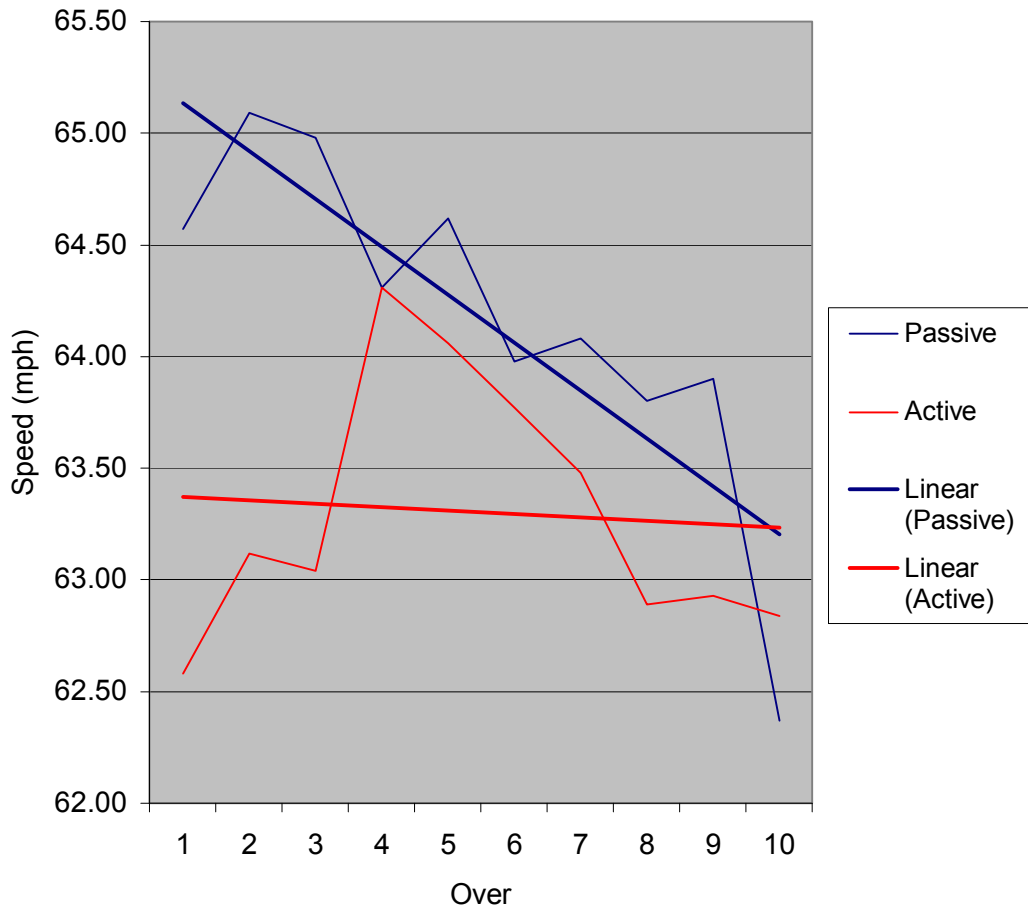


Figure 6. Average bowling speed for passive and active recovery during the test.

Figure 6 displays a trace of the average bowling speeds during the spells. It can be seen that the bowling speed starts much lower when using active recovery however the decline of bowling speed during the spell is much less that using a passive recovery due to the gradient of the line. At the tenth over the two lines have crossed suggesting that speed could be maintained for longer duration using an active recovery.

4.3 Statistical Analysis of Bowling Speeds

Following a repeated measures one-way analysis of variance (ANOVA) there were no significant differences between the two speeds in a spell. However a paired samples t test revealed statistically on average subjects bowl faster using a passive recovery ($M = 64.2$) then using an active recovery ($M = 63.3$), $t(359) = 5.906$, $p = .000$, $\alpha = .05$. This could be attributed to the active recovery starting at a much slower speed than the passive recovery. Paired t tests were conducted to identify if there was a difference between the means of individual overs. Overs were paired and the mean speeds were compared for significant differences.

Table 5. Paired *t* test results showing significant pairings (2 tailed)

Pairing	Significance
Passive over 1 - Passive over 2	.000
Active over 1 – Active over 4	.000
Active over 1 – Active over 5	.000
Active over 1 – Active over 6	.001
Active over 1 – Active over 7	.001
Passive over 1 – Active over 1	.000
Passive over 2 – Active over 2	.000
Passive over 3 – Active over 3	.000
Passive over 8 – Active over 8	.042
Passive over 9 – Active over 9	.034

The table shows that using a passive recovery a significant difference in speed occurs between the first and tenth over. There is no significant difference however between the speed of the first over and the tenth over ($P > .05$) using an active recovery. When an active recovery was used the sixth and seventh overs were significantly faster ($P < .05$) than the first over. From figure 5 it can be seen that when using an active recovery the bowlers started much slower, this has been shown as significantly slower, as has the second and third overs, however the speeds are significantly faster during the eighth and ninth overs using active recovery.

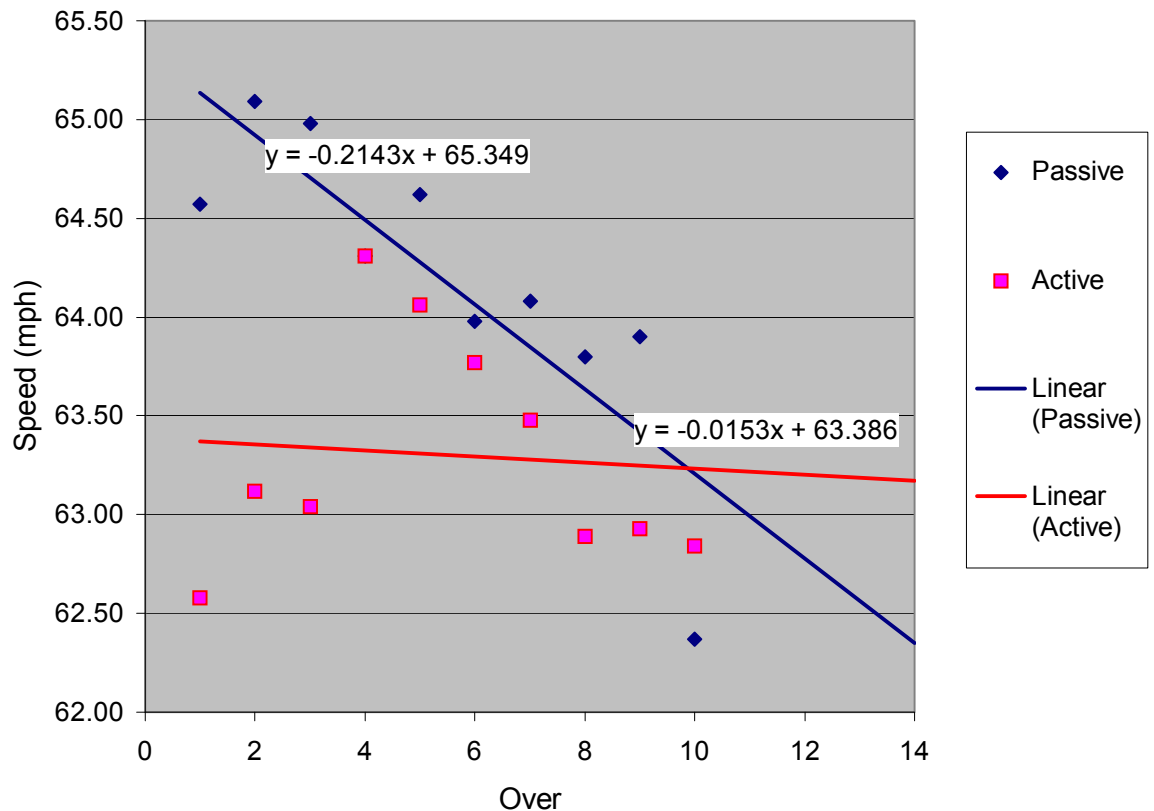


Figure 7. Predicted bowling speeds during a 14 over spell using passive and active recovery.

Figure 7 shows the bowling data of the two studies. The graph displays a forecast of the treadmill and a linear regression value. The graph shows that if the study were to continue for four more overs the average bowling speed for bowlers would be less than 62.5mph^{-1} using an active recovery, whereas speed is predicted to be above 63mph^{-1} for active recovery. These values are only a guide, as they do not take into account the fatiguing physiological elements of bowling. The linear regression line shows that for passive recovery the bowler's speed declines by 0.21mph^{-1} each over, whereas speed declines by 0.015mph^{-1} each over for active recovery.

CHAPTER VI
CONCLUSION

6.1 Introduction

The initial purpose of the current study was to identify the effect of an active or a passive recovery on bowling speed. The study has discovered that there are no significant differences in bowling speed when using the two recoveries. There are significant differences within bowling spells however. Speed is significantly slower when using passive recovery from the first and tenth over, whereas using an active recovery speed becomes significantly quicker during the fifth, sixth and seventh overs. Linear regression shows that speed decreases at a greater rate using passive recovery than that of active recovery, which coincides with a greater fatigue index for passive recovery. Therefore, in summary the differing recovery periods produce differing results, a passive recovery allowed bowlers to attain a greater peak speed, but an active recovery allowed bowlers to fatigue at a slower rate, and maintain their speed to a greater extent during a spell.

6.2 Implications for coaches and players

The main concerns with the methods in a study of this nature was feasibility. Due to the nature of current research regarding active recovery and the methods used a research design that considered the forms and rules of the game was required, and achieved by the simple protocol used. The results as discussed have implications for coaches although there is an evident need for future research. The use of an active recovery will be beneficial to

bowlers who work at a very high intensity ($\%VO_{2max}$) for the duration of the delivery. This is due to the greater demands placed on the CV system and more forceful muscular contractions. This can cause an increase in blood lactate, but as the literature suggests intermittent active recovery can increase the removal of lactic acid. These physiological processes will enable the bowler to reproduce fast deliveries due to the removal of lactic acid. The results also suggest a bowler can apply an active recovery to maintain bowling speed, although the speed will be slower in doing so for the first ten overs. This can be of great use to a coach as in games where fast bowlers are required to bowl for a long spell (over ten overs) their speed will be quicker in the latter overs and more consistent than if they were to use a passive recovery, this relates to the aforesaid points on psychological advantage and reaction time for the batsmen by Abernethy (1985).

6.3 Limitations

The current study has produced a range of descriptive and statistical results that can have implications for players and coaches as discussed. There is a great need for more physiological variables to be considered. The feasibility as mentioned was the underlying theme of the active recovery, therefore online methods of calculating VO_2 and RER were not feasible as this cannot be used on the cricket field. Another limitation of the study was the lack of VO_2 test, this would enable the subject to work at more precise value of VO_{2max} but again this would include an online method of recording data, which cannot be achieved on the cricket field. The method aimed to raise the HR as a measure of blood flow. A catheter could be used to accurately

measure blood flow, however this procedure is extremely invasive, but would give an accurate reading if an increase in blood flow occurred. A final variable that could have been measured was blood lactate, although from the review of literature it was evident that the build up of blood lactate is generally low so should not pose an immediate detriment to bowling speed. A consideration must be made to the temporal scale of the study. The study was conducted in the winter months, the off-season in cricket. Although the subjects were well trained they lacked match practice. This lack of bowler specific fitness may affect the speeds achieved throughout the study. The final limitation to the study relates to research by Hanley *et al* (2003) whereby 5 out of 74 technical variables can impact ball release speed. This does not take into account physiological differences and environmental differences. This demonstrates that much greater control is necessary in a study of this nature as one element may greatly affect the results. A limitation within the protocol was the order of recovery. All subjects completed the passive recovery first and the active recovery second. This could have a psychological affect, as the subjects may not have worked at 100% intensity the second time around. A more appropriate method where one half the subjects did an order of passive then active recovery and the other half did it in order of active then passive may generate a greater quality in results.

6.4 Future research recommendations

The current study has demonstrated there is a need for future research within this area, and due to the limitations there are many areas that future researchers can focus upon. The subject size is certainly an area that can be improved upon and it is clearly evident that a larger sample size is necessary in order to achieve a more accurate representation of the cricketing population. Future research should also be more specific to cater for different speed of bowlers. Bowlers vary in pace, and an effort should be made to group bowlers, so that differences between a cohort can be more specifically scrutinised.

Future research can also aim to measure more physiological variables under differing conditions. An example would be to assess active recovery in varying climates, as this may greatly effect the application of the active recovery, and identifying blood lactate concentrations and VO_2 values. Future researchers could use video analysis in order to relate the specific HR reading with each delivery. The data could then lend itself to further investigation such as the HR at different stages of the over, this type of method as seen in the study by Burnett *et al* (2005).

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APPENDICIES

APPENDIX A

INFORMED CONSENT

PARTICIPANT CONSENT FORM

Outline

For this study the subject will be required to complete a ten over spell of bowling whilst having their heart rate and bowling speeds recorded.

Details

The participant will have a heart rate transmitter belt fixed around their chest (with an electrolyte gel on the transmitters), and a watch on their front bowling arm wrist to monitor the heart rate. The signal shall be tested for quality. The subject will complete an eight-minute warm up. This should consist of a four-minute progressive run and three minutes of stretching, with an extra minute for participants to complete their own stretches. The subject will then have an opportunity for three practice deliveries prior to the study.

Once the warm up is complete the heart rate monitor shall begin recording the ten over bowling spell. The subject will deliver six legitimate balls, ensuring that the front foot is not overstepping the front line. Once the over is complete the bowler will have a three-minute recovery period. Once the recovery period is finished the bowler will complete the next over until the bowling spell is complete.

Recovery Periods

Passive Recovery

During the recovery periods the bowler will have a passive recovery period. This is to stimulate the cricket environment, as the bowlers will rarely field the ball during a spell. The average fielder will have to field the ball 8.1 balls per hour. In order to replicate this the bowler will have to field 8 balls rolled out to them and throw them back into a wicketkeeper, to simulate the cricket environment. The administrator will randomly assign the fielding drills. The bowler must simulate the recovery period as much as possible so there will be limited talking, no lavatory breaks and fluid replenishment will be allowed at the end of the over. The resting bowler must also “walk in” with the bowler who is currently in there over.

Active recovery

During the active recovery intermittent exercise is required to maintain heart rate and work at a calculated percentage of $VO_{2\max}$ (55%). A predicted value will be assigned to the subject prior to the test. It is the subject's responsibility to complete intermittent exercise such as shuttle runs or dynamic stretching to maintain the prescribed heart rate. The heart rate will also be monitored by the administrator to ensure validity. During this protocol eight fielding drills will be randomly distributed per hour, there will be limited talking, no lavatory breaks and fluid replenishment will be allowed at the end of the over.

Validity

To ensure the validity of the test and the quality of results the mean velocity of the first six deliveries shall be calculated. The bowler must then keep their speed within 10% of that value to ensure that the subject is performing with maximum effort throughout the study.

Physical Active Readiness Questionnaire

Circle appropriate answer

1. Has your doctor ever said that you have a heart condition or can only do exercise as prescribed by your doctor? Y/N

2. Do you have any great discomfort when partaking in exercise? Y/N

3. Do you have a bone or joint problem that can be made worse by taking part in physical activity? Y/N

4. Is your doctor currently prescribing you drugs or medication for blood pressure or heart condition? Y/N

5. Do you lose your balance because of dizziness or do you ever lose consciousness? Y/N

6. Do you feel pain in your chest when partaking in exercise? Y/N

7. In the past month had you had chest pain when not partaking in physical activity?

Participant Consent Form

Please **initial** each statement

- I have read and understood the procedure of the study fully and have had an opportunity to ask questions and consider the study.
- I understand that the study will be physically demanding and I have the opportunity to leave the study at any point without giving reason
- I give consent to take part in this study

Name (CAPITALS).....

D.O.B.....

Recovery format (delete as necessary) Passive / Active

Signature

Date.....

APPENDIX B

PILOT STUDY

Bowling speed using passive recovery (km/h⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8
1	115.9	120.2	117	114.1	116	112.8	116.6	116
2	117.1	117	114.2	116.4	115.5	111.5	114.5	114.7
3	118.6	116.3	117.6	111.2	116.6	113.2	115	112.8
4	117.6	115.8	118.6	115.3	116.3	113.2	112.4	117.2
5	118.3	115.3	114.2	116.5	115.5	112.4	113.5	111.6
6	118.5	117.1	116.6	112.9	109.8	110.4	116.3	110.6

Heart rate data grouped into 10-minute averages

Time (mins)	Pilot Study (bpm ⁻¹)
0-10	142.1
10-20	160.7
20-30	158.3
30-40	163.7
40-50	163.4
50-60	173.7

APPENDIX C

HEART RATE DATA

SUBJECT 1. Heart rate data grouped into 10-minute averages

Time (mins)	Passive recovery (bpm ⁻¹)	Active recovery (bpm ⁻¹)
0-10	142.2	154.8
10-20	158.1	161.2
20-30	159.4	167.2
30-40	155.2	163.8
40-50	145.1	167.9
50-60	154.4	165.7
60-end	154.8	163.7

SUBJECT 2. Heart rate data grouped into 10-minute average

Time (mins)	Passive recovery (bpm ⁻¹)	Active recovery (bpm ⁻¹)
0-10	156.6	156.5
10-20	159.6	156.4
20-30	161	158.7
30-40	166.4	161
40-50	150	151.6
50-60	161.2	154.2
60-end	154	158.1

SUBJECT 3. Heart rate data grouped into 10-minute average

Time (mins)	Passive recovery (bpm ⁻¹)	Active recovery (bpm ⁻¹)
0-10	130	116.1
10-20	124.7	126
20-30	140.2	128.7
30-40	142.6	129.5
40-50	144.5	124
50-60	143.7	134
60-end	137.8	139.1

SUBJECT 4. Heart rate data grouped into 10-minute average

Time (mins)	Passive recovery (bpm ⁻¹)	Active recovery (bpm ⁻¹)
0-10	124.7	132.8
10-20	120.7	136.2
20-30	128.8	149.3
30-40	131.1	149.4
40-50	132.6	144.3
50-60	134.2	153.7
60-end	129	149.4

SUBJECT 5. Heart rate data grouped into 10-minute average

Time (mins)	Passive recovery (bpm ⁻¹)	Active recovery (bpm ⁻¹)
0-10	160.7	162.8
10-20	158.8	163.3
20-30	171.9	174.7
30-40	167.5	170.3
40-50	173.6	172.8
50-60	165.6	159.8
60-end	183.2	179.2

SUBJECT 6. Heart rate data grouped into 10-minute average

Time (mins)	Passive recovery (bpm ⁻¹)	Active recovery (bpm ⁻¹)
0-10	143.8	139.8
10-20	135.8	136.8
20-30	150.7	141
30-40	139.7	139.4
40-50	148.1	140.3
50-60	140.6	145.7
60-end	163	N/A

APPENDIX C

BOWLING SPEED

SUBJECT 1

Passive Recovery. Bowling speed (mph⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	64.5	66.5	66.6	65.3	64.4	64.5	65.7	63	61.9	61.4
2	62.9	65.4	67.4	66.1	66.6	64.5	62.6	60	61.4	63.3
3	63.5	66.9	68	63.1	64.6	60.5	64.2	61.6	63.8	60.3
4	65.1	65.9	67.7	66	65.3	63	63.9	61.9	61.3	60.9
5	66.1	64.8	68.3	62.4	66	62.8	62.6	61.3	61.3	61.1
6	65.3	66.9	65.6	67.2	63.4	61.7	62	65.4	61.8	64

Active Recovery. Bowling speed (mph⁻¹)

Delivery number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	58.3	62.8	60.3	62.9	62.6	60.6	60.4	58.6	58.4	60.2
2	60.6	64.3	61.8	62.5	60.3	60.8	62.6	60.5	57.9	60.6
3	62.6	64.7	62.6	62.6	63.8	60.8	61.5	59.3	59.8	58.2
4	61	62.9	64.4	59.9	61.7	59	63.5	58.7	59.6	57.2
5	64.1	62.4	60.1	64	61.5	63.6	62.4	61.8	60.1	59
6	64.8	63.5	63.3	62.5	62.7	61.5	64.4	60.7	60.3	58.4

SUBJECT 2

Passive Recovery. Bowling speed (mph⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	68.2	71	67.6	67.7	67.3	69.1	66.8	68.5	66.2	65
2	69	68.1	67	67.1	67.7	68	68.7	67.9	66.9	65.1
3	69	67.6	65	66.9	67.2	68.1	66.9	67.1	66.9	66.1
4	68.6	67.8	67.6	66.6	66.8	68.5	69.4	66.7	65.3	66.3
5	67.6	68.3	67.3	67.1	67.5	68.1	67.8	67.2	67.2	65.3
6	68.7	67	67.2	67.1	63.4	67.2	64.6	67.2	67.7	66.8

Active Recovery. Bowling speed (mph⁻¹)

Delivery number	Over 1	Over 2	Over3	Over 4	Over 5	Over 6	Over 7	Over 8	Over 9	Over 10
1	65.5	66.4	65.3	64.9	66.8	67.1	69.1	65.7	68.5	67.1
2	64.4	67	67.7	69.6	69.3	68	65	70.8	69.8	68.4
3	66.4	68.2	68.4	70.3	67.6	69.9	66.6	65.2	66	68.2
4	66.7	67.3	66.5	70.6	66.3	67.9	68.3	67.8	66.4	68.7
5	66.5	68.4	66.5	70.4	66.9	68.5	66.2	69.8	69.3	69.2
6	67.7	66.9	67.5	68.4	70.1	67.2	71.4	66.2	65.5	65.6

SUBJECT 3

Passive Recovery. Bowling speed (mph⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	68.2	69.9	69.1	69.5	72.5	69.7	69.9	72.1	69.8	66.9
2	68.3	69.9	70.1	71.7	71.1	67.5	69	68.3	69.8	70.3
3	66.4	68.6	71.1	68.8	71.1	70.7	72.3	66.8	69	68.8
4	69	68.7	70.7	68.8	69.9	71.5	67.8	70.2	69.8	64.7
5	68	67.8	67.8	70.6	68.1	69.5	68.2	69.8	70.6	64.6
6	69.4	68.1	69	70	70.4	71.4	70.6	69.1	68.6	66.8

Active Recovery. Bowling speed (mph⁻¹)

Delivery number	Over 1	Over 2	Over3	Over 4	Over 5	Over 6	Over 7	Over 8	Over 9	Over 10
1	64.6	65	69.4	69.2	69.7	68.3	67.3	66.2	66.2	67.5
2	66.4	65.9	69.4	69.1	68	70	65.9	67.8	68.9	65.8
3	64.8	65.5	67	68.4	68.7	67.6	65.7	65.3	67.9	69
4	64.1	67.2	66.8	70.3	66.9	66	67.9	67.1	66.1	66.8
5	65	64.9	68.3	68.4	69.4	69	64.9	64.7	66.6	68
6	65.5	65	68.3	69.7	68.4	69	68.5	64.3	68	66.6

SUBJECT 4

Passive Recovery. Bowling speed (mph⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	59.4	57.7	57.3	56.7	59.5	60.3	60.9	56	55.9	54.7
2	60.3	58.5	58.2	60.1	59.4	59.6	59.6	58.3	59.4	56.9
3	60.3	58.5	58.8	61	59.4	59.3	59	56.8	57.9	52.7
4	59.2	58.5	59.2	60.5	57.7	59.5	57.9	59.4	57.8	58.3
5	60.4	58.3	59.2	58	58.5	57.7	59.3	60	57.9	57.5
6	57.5	58.6	57.4	58.5	59.2	59.5	56.9	61.2	56.5	56.4

Active Recovery. Bowling speed (mph⁻¹)

Delivery number	Over 1	Over 2	Over3	Over 4	Over 5	Over 6	Over 7	Over 8	Over 9	Over 10
1	56.1	55.1	55.2	60.9	59.6	58	58.1	55.9	60.1	57.3
2	56.5	56.3	58.3	60.1	59.1	59.2	58.1	57.5	60.1	55.2
3	56.7	56.3	58.3	59.7	59.9	60.4	57.4	57.5	60.3	56.6
4	59.1	54.7	57.9	59	59	58.3	57.4	58.1	58.8	55.6
5	56.7	58.2	56.6	58.9	57.8	58.1	58.6	58.3	54.4	57.2
6	57.5	57.6	56.1	58.1	59.5	57.8	57	57.1	58.4	58.6

SUBJECT 5

Passive Recovery. Bowling speed (mph⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	70	70.3	68.7	59.1	72.2	70.8	69.8	68.9	70.5	65.1
2	70.4	70.5	70.1	67.6	70.2	60.5	68.3	67.2	70.6	69.9
3	71.7	70.8	69.7	67.4	70.6	67.6	68.5	68.7	69.3	69.7
4	69	70.3	68.6	68	70.9	60.4	69.5	68.9	69.3	68.7
5	59.2	71.5	69.2	69	59	61.3	58.1	69.8	68.8	65.1
6	69.1	68.9	67.9	70.8	67.6	70.6	68.6	68.7	70.5	70.1

Active Recovery. Bowling speed (mph⁻¹)

Delivery number	Over 1	Over 2	Over3	Over 4	Over 5	Over 6	Over 7	Over 8	Over 9	Over 10
1	68.3	69.8	66.3	68.1	68.5	68.3	69.7	67.8	66.8	67.7
2	67.3	65.5	68.8	66.5	65.9	70.5	66.8	69.9	65.5	66.7
3	68.5	67.7	65	68.9	67.8	67.1	67.3	67.7	64.7	67.2
4	66.6	68.2	66.2	69.2	69.3	69.2	66.8	68.1	65.7	67.2
5	66.6	68.5	65.6	69.4	72.4	69.2	66.8	65.7	65	68
6	68.2	68.8	67.6	68.4	70.1	66.4	68.7	69.5	66	68.1

SUBJECT 6

Passive Recovery. Bowling speed (mph⁻¹)

Delivery Number	Over1	Over2	Over3	Over4	Over5	Over6	Over7	Over8	Over9	Over10
1	59.4	57.6	57.2	57	58.3	58.5	58.3	56.9	57.7	54.4
2	58.8	59.6	58.4	56.7	59.2	58.7	57.5	55.9	56.6	54.4
3	58.1	59.2	59.6	57.7	58.1	58	57.9	56.1	59	56
4	57.8	56.8	58.4	58.3	57.6	58.3	58.2	56.7	58.3	56.2
5	58.1	58.8	60.1	58.4	58.4	57.7	57.7	57.2	57.2	55.2
6	58	59.7	58.1	58.4	57.2	58.5	57.8	55.9	57.9	56.4

Active Recovery. Bowling speed (mph⁻¹)

Delivery number	Over 1	Over 2	Over3	Over 4	Over 5	Over 6	Over 7	Over 8	Over 9	Over 10
1	57.6	58.3	58	57	57.3	57.1	58	58.1	58.2	58
2	58.3	56.8	57.4	57.5	57.2	58.9	59.9	57.7	58.2	58.7
3	58	60.3	56.8	56.7	58.3	56.7	58.3	58.5	59.2	59
4	57.9	56.5	57.5	58	57	59.5	57.2	58	58.8	58.4
5	57	57	56.3	58.7	57.6	56.5	58	58.1	60.2	59
6	56.9	58.4	58	56.5	59.2	59.6	59.7	60	59.6	59.1

APPENDIX D

SPSS OUTPUT

Fatigue Index Data

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Passive	12.7750	6	3.63159	1.48259
	Active	9.7150	6	1.79741	.73379

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Passive & Active	6	.543	.266

Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Passive - Active	3.06000	3.05464	1.24705	-.14565	6.26565	2.454	5	.058

Paired T Test Active vs. Passive bowling Speeds

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Passive1	64.5694	36	4.66781	.77797
	Passive2	65.0917	36	4.99184	.83197
Pair 2	Passive1	64.5694	36	4.66781	.77797
	Passive3	64.9778	36	4.83559	.80593
Pair 3	Passive1	64.5694	36	4.66781	.77797
	Passive4	64.3111	36	4.84637	.80773
Pair 4	Passive1	64.5694	36	4.66781	.77797
	Passive5	64.6194	36	5.12611	.85435
Pair 5	Passive1	64.5694	36	4.66781	.77797
	Passive6	63.9750	36	4.85453	.80909
Pair 6	Passive1	64.5694	36	4.66781	.77797
	Passive7	64.0778	36	4.90854	.81809
Pair 7	Passive1	64.5694	36	4.66781	.77797
	Passive8	63.7972	36	5.26658	.87776
Pair 8	Passive1	64.5694	36	4.66781	.77797
	Passive9	63.9000	36	5.25558	.87593
Pair 9	Passive1	64.5694	36	4.66781	.77797
	Passive10	62.3722	36	5.38599	.89767
Pair 10	Active1	62.5778	36	4.29825	.71637
	Active2	63.1194	36	4.69686	.78281
Pair 11	Active1	62.5778	36	4.29825	.71637
	Active3	63.0417	36	4.75198	.79200
Pair 12	Active1	62.5778	36	4.29825	.71637
	Active4	64.3139	36	5.00646	.83441
Pair 13	Active1	62.5778	36	4.29825	.71637
	Active5	64.0611	36	4.81292	.80215
Pair 14	Active1	62.5778	36	4.29825	.71637
	Active6	63.7667	36	4.83960	.80660
Pair 15	Active1	62.5778	36	4.29825	.71637
	Active7	63.4833	36	4.43998	.74000
Pair 16	Active1	62.5778	36	4.29825	.71637

	Active8	62.8889	36	4.68126	.78021
Pair 17	Active1	62.5778	36	4.29825	.71637
	Active9	62.9250	36	4.21693	.70282
Pair 18	Active1	62.5778	36	4.29825	.71637
	Active10	62.8361	36	4.92702	.82117
Pair 19	Passive1	64.5694	36	4.66781	.77797
	Active1	62.5778	36	4.29825	.71637
Pair 20	Passive2	65.0917	36	4.99184	.83197
	Active2	63.1194	36	4.69686	.78281
Pair 21	Passive3	64.9778	36	4.83559	.80593
	Active3	63.0417	36	4.75198	.79200
Pair 22	Passive4	64.3111	36	4.84637	.80773
	Active4	64.3139	36	5.00646	.83441
Pair 23	Passive5	64.6194	36	5.12611	.85435
	Active5	64.0611	36	4.81292	.80215
Pair 24	Passive6	63.9750	36	4.85453	.80909
	Active6	63.7667	36	4.83960	.80660
Pair 25	Passive7	64.0778	36	4.90854	.81809
	Active7	63.4833	36	4.43998	.74000
Pair 26	Passive8	63.7972	36	5.26658	.87776
	Active8	62.8889	36	4.68126	.78021
Pair 27	Passive9	63.9000	36	5.25558	.87593
	Active9	62.9250	36	4.21693	.70282
Pair 28	Passive10	62.3722	36	5.38599	.89767
	Active10	62.8361	36	4.92702	.82117

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Passive1 & Passive2	36	.866	.000
Pair 2	Passive1 & Passive3	36	.852	.000
Pair 3	Passive1 & Passive4	36	.786	.000
Pair 4	Passive1 & Passive5	36	.927	.000
Pair 5	Passive1 & Passive6	36	.826	.000
Pair 6	Passive1 & Passive7	36	.932	.000
Pair 7	Passive1 & Passive8	36	.858	.000
Pair 8	Passive1 & Passive9	36	.876	.000
Pair 9	Passive1 & Passive10	36	.888	.000
Pair 10	Active1 & Active2	36	.926	.000
Pair 11	Active1 & Active3	36	.907	.000
Pair 12	Active1 & Active4	36	.894	.000
Pair 13	Active1 & Active5	36	.900	.000
Pair 14	Active1 & Active6	36	.910	.000
Pair 15	Active1 & Active7	36	.940	.000
Pair 16	Active1 & Active8	36	.907	.000
Pair 17	Active1 & Active9	36	.821	.000
Pair 18	Active1 & Active10	36	.864	.000
Pair 19	Passive1 & Active1	36	.880	.000
Pair 20	Passive2 & Active2	36	.945	.000
Pair 21	Passive3 & Active3	36	.883	.000
Pair 22	Passive4 & Active4	36	.842	.000
Pair 23	Passive5 & Active5	36	.774	.000
Pair 24	Passive6 & Active6	36	.764	.000
Pair 25	Passive7 & Active7	36	.819	.000
Pair 26	Passive8 & Active8	36	.872	.000
Pair 27	Passive9 & Active9	36	.865	.000
Pair 28	Passive10 & Active10	36	.856	.000

Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Passive1 - Passive2	-.52222	2.52135	.42023	-1.37532	.33088	-1.243	35	.2
Pair 2	Passive1 - Passive3	-.40833	2.59146	.43191	-1.28516	.46849	-.945	35	.3
Pair 3	Passive1 - Passive4	.25833	3.11754	.51959	-.79649	1.31316	.497	35	.6
Pair 4	Passive1 - Passive5	-.05000	1.92954	.32159	-.70286	.60286	-.155	35	.8
Pair 5	Passive1 - Passive6	.59444	2.81506	.46918	-.35803	1.54692	1.267	35	.2
Pair 6	Passive1 - Passive7	.49167	1.77561	.29593	-.10911	1.09245	1.661	35	.1
Pair 7	Passive1 - Passive8	.77222	2.70941	.45157	-.14451	1.68896	1.710	35	.0
Pair 8	Passive1 - Passive9	.66944	2.53589	.42265	-.18858	1.52747	1.584	35	.1
Pair 9	Passive1 - Passive10	2.19722	2.47934	.41322	1.35833	3.03611	5.317	35	.0
Pair 10	Active1 - Active2	-.54167	1.77190	.29532	-1.14119	.05786	-1.834	35	.0
Pair 11	Active1 - Active3	-.46389	1.99802	.33300	-1.13992	.21214	-1.393	35	.1
Pair 12	Active1 - Active4	-1.73611	2.24743	.37457	-2.49653	-.97569	-4.635	35	.0
Pair 13	Active1 - Active5	-1.48333	2.10054	.35009	-2.19406	-.77261	-4.237	35	.0
Pair 14	Active1 - Active6	-1.18889	2.00909	.33485	-1.86867	-.50911	-3.551	35	.0
Pair 15	Active1 - Active7	-.90556	1.51958	.25326	-1.41971	-.39141	-3.576	35	.0
Pair 16	Active1 - Active8	-.31111	1.97466	.32911	-.97924	.35702	-.945	35	.3
Pair 17	Active1 - Active9	-.34722	2.55080	.42513	-1.21029	.51584	-.817	35	.4
Pair 18	Active1 - Active10	-.25833	2.48071	.41345	-1.09769	.58102	-.625	35	.5

Pair 19	Passive1 - Active1	1.99167	2.22433	.37072	1.23906	2.74427	5.372	35	.0
Pair 20	Passive2 - Active2	1.97222	1.63578	.27263	1.41875	2.52569	7.234	35	.0
Pair 21	Passive3 - Active3	1.93611	2.32504	.38751	1.14943	2.72279	4.996	35	.0
Pair 22	Passive4 - Active4	-.00278	2.77257	.46209	-.94088	.93532	-.006	35	.9
Pair 23	Passive5 - Active5	.55833	3.35290	.55882	-.57612	1.69279	.999	35	.3
Pair 24	Passive6 - Active6	.20833	3.33324	.55554	-.91947	1.33614	.375	35	.7
Pair 25	Passive7 - Active7	.59444	2.84725	.47454	-.36893	1.55781	1.253	35	.2
Pair 26	Passive8 - Active8	.90833	2.57708	.42951	.03637	1.78029	2.115	35	.0
Pair 27	Passive9 - Active9	.97500	2.65711	.44285	.07596	1.87404	2.202	35	.0
Pair 28	Passive10 - Active10	-.46389	2.80633	.46772	-1.41342	.48564	-.992	35	.3

ANOVA with Friedman's Test and Tukey's Test for Nonadditivity

	Sum of Squares	df	Mean Square	Friedman's Chi-Square	Sig
Between People	7710.851	35	220.310		

Within People	Between Items	193.458	9	21.495	6.128	.000
	F Nonadditivity	7.836 ^a	1	7.836	2.243	.135
	€ Balance	1097.163	314	3.494		
	ξ Total					
	i					
	κ					
	λ	1104.999	315	3.508		
	ε					
	l					
	Total	1298.457	324	4.008		
Total		9009.308	359	25.096		

Grand Mean = 64.1692

a. Tukey's estimate of power to which observations must be raised to achieve additivity = 3.791.

Intraclass Correlation Coefficient

	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.844	.773	.904	54.973	35	324	.000
Average Measures	.982	.971	.990	54.973	35	324	.000

One-way random effects model where people effects are random.

