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Original Research

A System or Method of Analysis for Injury Prevention in Sports, Youth Fastpitch Softball Pitchers: A Pilot Study

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ABSTRACT

Background

The prevalence of softball injuries in young pitchers is increasing with more injuries in the upper extremity in the beginning of the season.

Research Question

Calculate the forces generated during the pitching motion of female youth pitchers at four main areas: the stride, hips, shoulder, and wrist for 2 groups. R1: u1≠u2.

Study Design

Pilot study, Cross-sectional design.

Level of Evidence

Level-2, Strength-B.

Methods

This study included a total of 15 female youth fastpitch softball pitchers (mean age, 14.33-years; mean weight, 59.01 kg) recruited to participate during the Fall Softball League (2014). Divided into two groups: 270° hip rotation group *vs.* a projected 360° hip rotation group.

Results

A paired sample *t*-test showed that the 2 groups (270° hip rotation and projected 360° hip rotation) were strongly and positively correlated (r=0.993, $p<0.001$). There was a significant average difference between 270° hip rotation and the projected 360° hip rotation forces (t14=12.996, $p<0.001$). On average, the projected 360° hip rotation forces were 580.68 N higher than 270° hip rotation forces (95% CI [676.51, 484.84].

Conclusion

The Current Method (CM) of pitching clearly uses the shoulder as the driving force of the pitch, as pitchers created 467.96 N of force at the shoulder. Pitchers who used 270° hip rotation produced an average of 147.33 N at the hip while these same individuals can create an average of 589.30 N with full hip rotation.

Clinical Relevance

Pitchers using the CM of pitching generated an average of 468 N of force at the shoulder. Identifying interruptions in the kinetic chain is the key to reducing injuries. This is accomplished by creating the ideal kinetic chain and teaching it through a certified pitching coach program. Once identified, interruptions can be modified and changed through exercises to strengthen and improve the kinetic chain.

Keywords

Softball injury prevention; Fastpitch softball; Windmill pitch; Female youth pitchers; Windmill biomechanics.

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INTRODUCTION

Injuries in youth (12-18-years-old) fastpitch softball pitchers are increasing as the demands on pitchers continue to escalate due to the increasing popularity and competitive nature of the sport.[1] Modification of programs to enhance pitchers' performance is imperative, especially for reducing the probability of injury.[2] There is insufficient literature examining injury prevention in youth softball pitchers.[3] This study identifies areas within pitching biomechanics that relate pain to injury vulnerability.[4,5]

There are key areas of coaching and pitching that need to be updated in the sport.[2] A pitching coach certification program and pitcher training are essential for injury prevention. The areas needing revising include strength and endurance training for the pitchers, skill training for the coaches to enable them to recognize biomechanical errors in pitching that may lead to injuries, and certification programs for coaches to ensure accountability.

Over two million young women, from 12-18-years-old, play fast-pitch softball each year in the United States with 368,734 of these girls playing in high school.[6,7] As the sport has grown, a competitive tournament circuit has been created allowing the girls to play softball year-round. Along with this increase in pitching opportunities, there is a lack of trained softball-pitching staff. This leaves many pitching coaches, without training and knowledge of proper mechanics, working with athletes.[3]

Adolescent female athletes present unique challenges. Coupled with high intensity physical training, the nutrient-poor American diet may predispose the adolescent female athlete to female athletic triad.[7] A decrease in bone density or brittle bones is related to hormonal imbalances. There is a public health concern when these young female pitchers are placed with coaches who are unfamiliar with the kinetics of fast-pitch and a female youth athlete's specific needs.[8] It is these factors and the intense demands of competition pitching that have produced an epidemic of fast-pitch injuries.

The prevalence of softball injuries in young pitchers is climbing, with more injuries in the upper extremity when compared to other position players, and more injuries occur at the beginning of the season.[9-12] Current research documents the increasing injuries among pitchers with estimates indicating a five-fold increase in pitching injuries from 2000 to 2009.[13] With no pitch counts or rest day regulationsyoung girls who are pitching using improper mechanics, while fatiguedor in pain, are predisposed to injury.[3]

Fast-pitch softball pitchers have comparatively the same risk for fatigue and injury as baseball pitchers, without any of the preventative injury measures.[14] Modifying programs to enhance pitchers' physical health, coordination, mechanics, and other factors reduces the likelihood of injury. Pitchers who continue to play with injuries put themselves at greater risk for more serious complications.

Research Question

What are the forces produced during the pitching motion of an average female youth pitcher at the following joints: stride, hips, shoulder, and wrist, using the current method of pitching?

Purpose

The purpose of this article is to examine the literature and illustrate the disparity existing in research on the current method of pitching in fastpitch softball and the injuries that stem from using the windmill pitch as a background for the pilot work to follow. This report will identify the mechanism of injury using the current method of fastpitch softball pitching. The results of this study will establish a basis for a public health campaign to design a prevention program to address this epidemic. The current method of pitching is defined in this study as any method utilized by a youth pitcher that goes against the natural physiology of the pitching movement. The principal reason the CM has to change is because it causes internal rotation of the shoulder and supplemental arm injuries.

Current Method Biomechanics Questions to Challenge

1. Internal rotation of the shoulder with forward bend of the torso;
2. Bent elbow with pull release at hip *versus* straight arm push past hip slightly;
3. Abduction of lag leg or ipsilateral leg without internal rotation of the femur versus that with internal rotation of the femur and hips;
4. Can hips be closed to 360° upon release or does it occur post pitch?

The Current Method

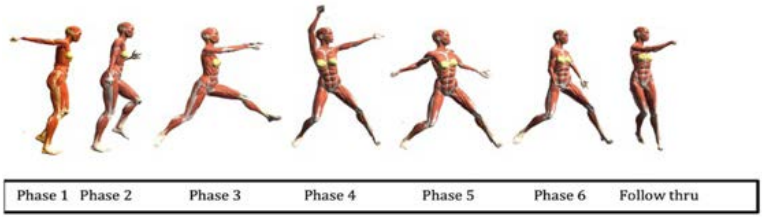
The phases of the windmill softball pitch are a context for looking at the pitcher from a side view. The pitching arm is equivalent to the clock hand moving counter-clockwise around the clock. The phases are based on the position of the humerus related to the torso as it travels through the sagittal plane.[15] In order to examine the windmill pitch, the motion is dissected into smaller phases.[15]

The term, current method (CM), will be used to describe the fast-pitch softball method most commonly discussed in the literature. In the review of the literature, the CM was found to be the method most often being studied or examined. Increasing injuries in the sport have triggered a movement in the literature to examine the kinetic chain of the windmill pitch. A pitching method to incorporate the essential elements of proper pitching mechanics based on physics and the physiology of movement will be examined. The interplay between pitching mechanics and the kinetic chain may contribute to acute and long-term injuries. The proper kinetic chain is similar to baseball's kinetic chain, continuous, while the CM kinetic chain, non-continuous (Figure 1).[16]

Cumulative Injury Disorder

The most common injury in softball pitchers is directly related to

Figure 1. *Phases of the Current Method*



Phase 1: arm behind the back; arm in internal rotation or neutral; weight on ipsilateral (lead) foot; clockwise backward movement from 6 to 9 o'clock position.21
Phase 2: 6 to 3 o'clock position; contralateral leg (lead leg) begins to lift; initiates Counter-clockwise upward movement from 6 to 3 o'clock.21
Phase 3: 3 to 12 o'clock position; arm begins external rotation; trunk rotation to same side; contralateral leg extended prior to foot contact; Arm continues to accelerate continues counterclockwise movement from 3 to 12 o'clock.21
Phase 4: 12 to 9 o'clock position; arm "opens up" to ipsilateral side (lag leg) with full external rotation; the humerus accelerates from 12 to 9 o'clock.21
Phase 5: 9 o'clock position to ball release; internal rotation of trunk and arm; arm adducted across body; release corresponds to movement from 9 o'clock to ball release.21
Follow-through: ball release with arm next to body.

the dynamics of the windmill pitch and the forces acting on the shoulder. Tears to the labrum, rotator cuff, Tommy John or ulnar collateral ligament injury, and other pitching injuries occur as a result of the repetitive stress and strain that result in micro-traumas to the shoulder. Over time coupled with general fatigue, the weakest link in the shoulder will be injured first.[17] Cumulative injury disorder describes the cycle of injury that these pitchers are going through and it may be calculated using the number of pitches thrown times the applied force on the joints.

The applied stress or accumulation of hundreds of pitches in these fatigued youth pitchers, who are more susceptible to break bones, can be destructive. During a weekend tournament softball pitchers throw 1000 to 1500 pitches.[18] The best pitcher on the softball team will pitch most of the games during a season.[9] The high forces experienced at the shoulder with the high number of pitches thrown make it easy to understand the increased potential for injury.[15]

When players are fatigued, they do not have efficient proficiency to control their form and as a result they develop dysfunctional coordination patterns, and the potential for injury is high. A baseline of coordination patterns and their unpredictability over consecutive pitches needs to be established to determine whether movement patterns might be a factor in injury risk.[15] The cumulative injury disorder (CID) calculations may be used as a baseline to assess injury potential in pitchers. CID can be determined by calculating the forces generated in the female pitcher during a pitch, , Force=mass×acceleration (F=m×a)obtained from the stride, hip, arm, and wrist during a pitch.

LITERATURE REVIEW

Public Health Epidemic Criteria

• Substantial burden on youth softball society, parents, and injured athletes.
• Injury burden is distributed unfairly because youth baseball has protective measures and the injury risk for each is comparable.
• Injury incidence and prevalence are increasing (suggesting preventability).
• Public and private concern about risk.
• Preventative strategies such as pitch counts and rest day regulations are not yet in place.

Large Burden on Youth Softball Society, Parents, and Injured Athletes

Youth pitchers are much different than adult pitchers, because young pitchers are continuously growing and developing, thus requiring longer recovery times from pitching.[1] The increase in the popularity of the sport has spurred growths in enrollment, with a lack of trained pitching coaches filling the void. Some coaches are unfamiliar with a female pitcher's specific needs: the physical care needed to maintain the growth curve of a continuously developing child; the nutritional care needed to protect their bones and growth cartilage that is susceptible to the repeated stress of micro-traumas; and, the need for sequential coordination drills in fast-pitch softball pitchers to ensure the proper timing of the pitch.[6]

The most common location of injuries in fast-pitch pitchers are those to the shoulder. This is likely a result of overuse as 76.4% of pitchers throw between 300-500 a game, some while using flawed mechanics.[5] The recurring strain on the upper extremity of the pitcher can lead to damages.[5] Extremely competitive travel and club teams, comprised of elite youth fast-pitch softball pitchers, have become progressively more widespread. Tournaments featuring these teams are usually held on weekends and often result in some pitchers throwing over 200 pitches in three or more games a day. These tournaments, extended seasons, and extreme training regimens are key elements to the increased risk for injuries in youth pitchers.[16]

Pitchers in these tournaments lack sufficient time to

recover from the shoulder pain, fatigue, weakness, and loss of strength and are not recovering their baseline strength with only one day of rest after pitching. This may be the cause of the increase in pregame pain and fatigue.[17] As the season progresses, the supraspinatus muscle, controlling shoulder forward flexion and external rotation, decreases in strength. Bilateral fatigue increases in the hips and scapular muscles, and unilateral fatigue occurs in the shoulder and arm muscles.[14,17] Youth pitchers compensate for fatigued muscles and joints by changing their pitching mechanics putting extra strain on the upper extremity and increasing their risk of tissue injury.[14,16,19]

Injury Burden is Distributed Unfairly

Muscle forces during the windmill pitch in softball are higher than in baseball pitching. The maximum force is generated during Phase 5, from the 9 o'clock to 6 o'clock position, which is the wrist snap.[19] Baseball researchers have classified fatigue as one of the most important risk factors for injury and a leading cause for surgery.[3,5,18] Baseball pitchers are limited to 210 pitches per week while softball pitchers can pitch 1200 to 1500 pitches in a long weekend tournament.[9] Softball teams usually pitch their number one pitcher for most games throughout a season, while baseball teams rotate pitchers.[9] When a pitcher uses improper biomechanics, and this motion is carried out repeatedly, the stress is comparable to 80-95% of the baseball pitch stress on the shoulder.[20]

Literature regarding the evaluation of injuries and their mechanism of action in fast-pitch pitchers is scarce.[3] Consistently mentioned throughout the literature is that the injury rate in softball is similar to or surpasses baseball.[15,20-22] Biomechanists discovered that the windmill pitch places strain on the shoulder comparable to baseball.[2,19,23,24] Shoulder injuries are common among youth softball pitchers.[3]

Injury Incidence and Prevalence are Increasing

Adolescent's injury risk factors include inadequate conditioning, deficient diet, cumulative fatigue, weak core muscles, poor scapular strength, and increased pitching activity. Identification of injury incidence in pitchers is essential in developing injury prevention tactics to keep these athletes healthy.[6] Past notions concerning the mechanics of the windmill pitch as safe are still evident in the softball culture. This belief is rooted in the historical perspective that the pitching motion is not harmful to the shoulder. Historically, the pitching method closely followed the natural mechanics of the body. The windmill pitch has evolved over time into the current method of pitching. Research has followed the progression of the pitching motion with limited investigation into the specific diagnostic mechanisms of injury for the 360° counter-clockwise motion of the windmill pitch.

The increase in youth pitching injuries is attributable, in part, to the rapid increase in pitching activity at the beginning of the season paired with an adolescent's weak core strength and poor paired scapular strength.[20] Adolescents have a 78% greater chance of getting injured during the first 6-weeks of the season and have a 61% chance of developing a shoulder injury. Moreover, 50% of injured pitchers lose more than 2-weeks of playing time.[6,25]

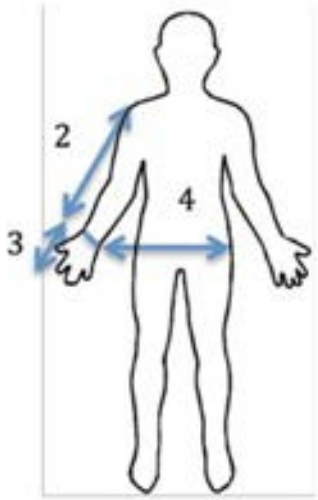
Public and Private Concern About Risk

Leading researchers in the field of sports science have stated a need for injury prevention strategies, such as pitch count and rest day regulations, to address risk factors associated with the abundance of tournament play.[3,4] The American Board of Pediatrics on Sports Medicine, for example, has recommended training principles for girls' softball because of the increase in injury incidence and to establish guidelines for injured pitchers for recovery.[13] These training principles include maximum pitch counts, physical training, and creating instruction in proper pitching mechanics.[26] Little League softball does have pitching regulations based on innings pitched, but research has concluded that inning counts and games pitched do not predict overall injury rates as well as pitch counts.[26] Descriptive studies for youth softball pitchers need to be performed to understand the connections between injuries, pitch count data, and innings played at all levels of play.

METHODS

This pilot study follows a descriptive cross-sectional study design with a total of 15 female youth fast pitch softball pitchers (mean age, 14.2-years; mean weight, 58.45 kg) recruited to participate during the fall softball league (2014). G Power 3.1 output parameters calculated total sample size at 15, power of 0.82, and degrees of freedom of 14. A paired samples t-test was used to report the difference between not using hip rotation during the pitch and using the hip during the pitch. The pitchers had to be currently pitching on their team's roster to be included in the study. The institutional review board approved this research as exempt. Informed consent

Figure 2. *Body Measurements for Calculations*

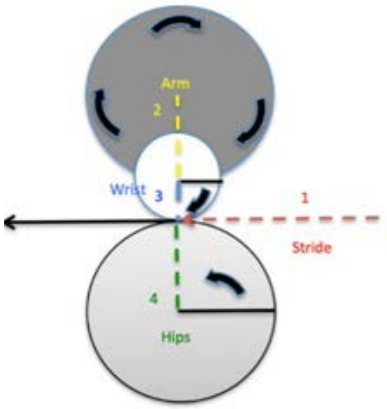


Youth measurements and their mass were used to calculate the forces generated during the pitch and are shown in Figure 3. The first measurement is the stride, the second is the arm, the third is the hand, and the fourth goes across the hip.

was obtained from all participants and their parents and/or guardians. The key variables in this study are the measurements and timing used to calculate potential velocity, acceleration, and force. A vector calculator and unit converter were used to calculate the forces created during the pitching movement.[27] Measurements (illustrated in Figure 2) and timing of individual segments (stride, arm, wrist, and hip) were used to calculate the forces generated at these segments by inserting this data into Newton's 2nd Law of Motion, F=m×a.

The magnitudes calculated for group 1 were at 270° of hip rotation (no hip), the magnitudes for group 2 were calculated as a projection using 360° or full rotation. The projection was used to show how much force is being lost per pitch when the pitcher does not utilize the hip and torso in the windmill pitch (Figure 3).

Figure 3. *Circumference and Radius Formulas and Illustration*



1. Stride length=Distance from pitching rubber to where lead foot strikes the ground,
stride acceleration=Distance/time/1 sec.
2. Arm length=Distance from shoulder joint to wrist joint circumference of a circle (2πr),
arm acceleration=2πr/time/1 sec.
3. Wrist length=Distance from wrist joint to tip of longest finger=circumference of a circle (2πr/4). The 4 is when the wrist moves 90° or ¼ of a circle,
wrist acceleration=2πr/4/time/1 sec.
4. Hip length=Distance from opposite hip across the body to the throwing arm at the hip=circumference of a circle (2πr/4). The 4 is when the hip moves 90° or ¼ of a circle when the pitcher utilizes the entire hip or 360° and the 16 is when the hip moves very little or 1/16 of a circle or 270°,
hip acceleration=2πr/16/time/1 sec. at 270°,
=2πr/4/time/1 sec. at 360°.

RESULTS AND DISCUSSION

Forces generated during the windmill pitch are calculated to establish a baseline for injury prevention. Data describing the forces generated for each participant at 270° and the data projections at 360° are located in Tables 1 and 2. Please keep in mind all pitchers were using the Current Method form and timing at 270° and 360° and the data at 360° only represents a change in hip rotation, not a change in all aspects of the pitch. The results of the paired samples *t*-test for the 2 groups (270° hip rotation and projected 360° hip rotation) were strongly and positively correlated (r=0.993, $p<0.001$). There was a significant average difference between 270° hip rotation and the projected 360° hip rotation forces (t14=12.996, $p<0.001$). On average the projected 360° hip rotation forces were 580.68 N higher than 270° hip rotation (95% CI [676.51, 484.85]. The measurements and times from the videos were used to calculate velocity. Once velocity was calculated these values were then divided by 1 second to calculate acceleration which was entered into the formula for Newton's 2nd Law of Motion, F=m×a. Other formulas used for calculations include speed=distance/time and acceleration=distance/time/second. The pitcher's stride length was computed by averaging all the pitchers stride lengths from 3-5 videos. An average stride length was determined to be 6 feet and was used for all participants. The same principle was used for the timing of hips and wrist snap for all participants; average time used was 0.066 seconds, each individual measurement was used for the hips and wrist. Individual weights were obtained from the pitchers and used for mass (m).

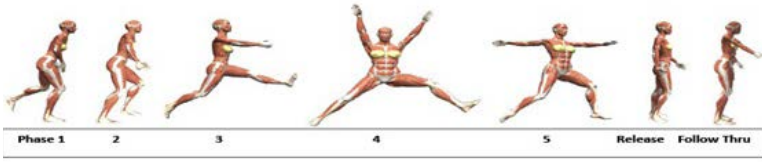
Table 1. *Total Force (Newton) Generated by Pitchers during the Windmill Pitch Using Hip at 270°*

Table 1: 270°	Stride (Newton)	Arm (Newton)	Wrist (Newton)	Hips (Newton)	Total Force (Newton)
P1	375.62	646.21	312.89	201.14	1349.80
P2	197.03	362.00	183.42	119.20	751.96
P3	308.42	622.51	274.27	180.96	1218.70
P4	266.39	488.67	259.15	143.46	1024.30
P5	215.24	470.56	271.85	151.51	969.56
P6	177.35	328.27	151.36	88.29	622.89
P7	322.51	542.94	277.72	185.09	1158.10
P8	260.27	488.67	240.63	138.83	999.26
P9	133.03	203.30	157.39	75.76	499.50
P10	282.37	456.56	267.35	138.82	1015.80
P11	335.90	575.14	272.70	194.04	1199.50
P12	228.04	418.60	196.08	113.13	850.28
P13	219.02	421.37	213.06	152.19	866.91
P14	196.65	333.20	181.81	94.40	717.89
P15	327.72	661.46	326.30	233.07	1336.00
Total	3845.50 N	7019.50 N	3585.90 N	2209.90 N	14,619.00 N
Average	256.37 N	467.96 N	239.07 N	147.33 N	974.60 N

The average force generated by these individuals during their pitches at 270° hip rotation was 974.60 N. Averages forces generated during the stride 256.37 N, the arm 467.96 N, the wrist 239.07 N, and the hip 147.33 N. The average forces generated for the same individuals were projected to calculate forces with one variable different, hip rotation at 360° instead of 270°. The average force projected by these individuals during their pitches was 1552.67 N.

The average forces for the stride, arm, and wrist generated for this group were the same as the 270° group because nothing was changed except the hip rotation; the stride 256.37, the arm 467.96 N, the wrist 239.07 N, and the hip 589.30 N. The projected hip rotation force was much greater in the 360° group, 589.30 N, than the 270° group, 147.33. The projected data for all 15 female youth pitchers is located in Table 2 for each variable and the total

Figure 4. *The Correct Kinetic Chain for Fast-pitch Softball Pitching*



Phase 1: Pitcher is taught to disguise the ball and perform warm up activities anterior to the body.
Phase 2: Pitchers face forward with feet pointing toward home plate or straight ahead. Pitcher pushes off from rubber with Lag foot. Lead leg begins to lift.
Phase 3: Lead leg continues to lift, and pitcher will "Show your Spike!" Pitcher shows spike to set up the proper alignment of the lead foot to land on the heel in Phase 5, a solid platform for kinetic chain activation. The arm begins its 360° counterclockwise rotation.
Phase 4: Hips and trunk rotate back to 270° the arm follows extending to the 12 o'clock position and lead leg extends toward target.
Phase 5: The pitcher pushes with back foot toward target to activate hip rotation as the hip leads the release. The hip then closes to 360° coupled with the torso, and scapula. As the hip reaches 360° the heel makes contact with the ground (feet facing forward toward target) as the shoulder flexes.
Phase 6: This sets up the upper arm to allow the elbow to be used as a catapult for the wrist snap/hip thrust and releasewith all forces directed toward the target for injury prevention. The hips finish in the neutral position as shoulder flexion finishes the pitch.
Follow Through: Finish following through straight ahead.

force for each pitcher. A blueprint for the ideal pitching motion in fast pitch softball pitchers, utilizing the windmill method based on injury prevention, is illustrated by phase in Figure 4.

Table 2. *Total Force (Newton) Generated by Pitchers during the Windmill Pitch Using Hip at 360°*

Table 2: 360°	Stride (Newton)	Arm (Newton)	Wrist (Newton)	Hips (Newton)	Total Force (Newton)
P1	375.62	646.21	312.89	804.57	2139.30
P2	197.03	362.00	183.42	476.79	1219.20
P3	308.42	622.51	274.27	723.85	1929.10
P4	266.39	488.67	259.15	573.82	1588.00
P5	215.24	470.56	271.85	606.02	1563.70
P6	177.35	328.27	151.36	353.17	1010.20
P7	322.51	542.94	277.72	740.37	1883.50
P8	260.27	488.67	240.63	555.31	1544.90
P9	133.03	203.30	157.39	303.03	796.75
P10	282.37	456.56	267.35	555.27	1561.60
P11	335.90	575.14	272.70	776.14	1959.90
P12	228.04	418.60	196.08	452.48	1295.20
P13	219.02	421.37	213.06	608.75	1462.20
P14	196.65	333.20	181.81	377.61	1089.30
P15	327.72	661.46	326.30	932.29	2247.80
Total	3845.50 N	7019.50 N	3585.90 N	8839.50 N	23,290.00 N
Average	256.37 N	467.96 N	239.07 N	589.30 N	1552.67 N

Limitations of the Study

The pitchers were from a small geographic area that included 1,050 softball players with approximately 175 pitchers. For future studies, a kilometer per hour assessment would be a better way to check the accuracy of the force calculations. The cross-sectional design of this study averaged results from one pitching encounter (3-5 pitch average). A longitudinal study, following these pitchers through-out their careers after an intervention and correction of mechanics, would be an ideal design. The 360° hip rotation projected group data only represents a change in hip rotation not a change in all aspects of the pitch. An average was used for stride length (182.88 centimeter) and average time (0.066 seconds) was used for hip rotation and wrist snap. Future studies will need to be performed on the correct pitching method using electromyography (EMG), motion analysis, range of motion analysis, muscle strength testing, balance assessment, strength training, and training on segmental sequencing or timing of the pitch to further develop a pitching method blueprint for injury prevention.

CONCLUSION

The CM of pitching clearly uses the shoulder as the driving force of the pitch. Pitchers in the 270° hip rotation group created 467.95 N of force at the shoulder.[20] Pitchers who used 270° hip rotation only produced 147.33 N at the hip while these same individuals have the potential to create 589.30 N with full hip rotation. The mechanics of the pitch must follow the natural movements of the body utilizing the stronger muscles and proper joint alignment. Softball lags behind all other youth sports in injury rate, recognition, and prevention safety rules. The windmill pitching style places a unique demand on the entire kinetic chain. The shoulder was designed for mobility not for strength and youth pitchers sustain significant shoulder instability patterns. The most common injuries are tears to the labrum, rotator cuff, and Tommy John or ulnar collateral ligament injury. The key to reducing these injuries is to update the regulations for youth softball and train coaches in off-season and preseason strength conditioning and proper mechanics, and how these mechanics should transition properly.[16,26] Pitching mechanics education is vital for keeping youth softball players healthy during the season.[24] When athletes cross train in various sports, the different movement patterns associated with each sport builds coordination. The use of additional movement patterns adds to the variability in coordination and may be an important etiological factor in decreasing softball pitching injuries.[15]

Recognizing the movement patterns involved in the windmill pitch will also allow better diagnosis of injury and specific rehabilitation and conditioning programs. A baseline of coordination patterns needs to be established to determine whether improper biomechanics play a part in injury risks.[15]

CONFLICTS OF INTEREST

The authors (Dr. Rebecca Fahey & Mr. Michael Fahey) declare that they have a provisional patent on their method of analysis for injury prevention in sports and have no other conflicts of interest.

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Challenges and Practices in the Implementation of Coaching Manuals in Selected Youth Handball Coaching Program in Addis Ababa, Ethiopia

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ABSTRACT

Objective
The aim of this study was to assess challenges and current practices in implementation of coaching manuals in selected Addis Ababa city, Ethiopia youth handball coaching program.

Methods
The study was employed a descriptive survey research method. Ten sample youth projects were selected, from twenty-four youth handball projects using stratified and purposive sampling technique. Thus, the samples of this study were 50 players, 10 coaches and 32 sport administrative officials. The data was collected through questionnaire and observation checklist and thus, analyzed using both quantitative and qualitative methods by describing statements and frequency counts and percentages.

Results
The findings of the study indicated that, lack of coordination work among the concerned stakeholders, due to financial scarcity; unavailability of adequate training materials and equipment, and the selection of trainees conducted just randomly without clearly stated criteria. Lack of suitable and standardized handball courts in the area and less emphasis given to maintain even the existing ones, the existed manual was not well designed and modified based on the trainee's age level since similar manual for both sex. Due to monitoring were limited to certain sport expertise, here were no concerned bodies in charge of finding immediate solutions to the problem that were faced by the coaches and trainees. Furthermore, due to lack of awareness of communities, trainee families did not support the training program.

Conclusion
This kind of implementations revealed that was exposed to failure to solve the confronted challenges. Therefore, attention must be paid to the availability of sport infrastructures and qualified human resources should be employed. In addition, special attention must be given to acquiring and developing resource material such as manuals and coaching kits, which may assist in improving knowledge and advancing the technical skills of sport experts and coaches.

Keywords
Handball; Program; Trainee; Coaching manual; Challenges; Coach; Implementation.

INTRODUCTION

Handball is one of the rapidly becoming popular games all over the world.[1-3] The handball game that we know today was developed in northern Europe at the end of the 1880s. Accordingly, it was popular in Sweden, Norway, Denmark and German. It believed that, Denmark was recognizing as the birth place of modern handball.[4] World's handball governing body was formed in 1928 and currently it has five member continental federations and 208 member countries.[5] The game handball was introduced into Ethiopia during the 1968 *via* university instructors. But still handball is not a big sport in Ethiopia with only about 144 registered

club players and only about 284 handball project centers of 7100 youth project trainees' nationwide (data of Ethiopian Handball Federation (ETHF) reported in 2018/19).[1,2]

There are strategic themes that are to be considered when coaching youth handball athletes. First, they should be able to develop young talents as much as possible. Alternatively, the coaches must at the same time when coaching the talents, keep the players, which are only playing since having handball as one of their hobbies. This requires different kind of an approach from the coach. Every practice must be planned with these two types of players in mind and the training should be given in same standard by using coaching manuals.[6,7] Thus, this study was intended to assess the current practice and challenges in implementation of youth handball coaching manual in selected Addis Ababa city handball coaching program.

METHODS

Research Design and Study Population

This study was used descriptive survey method. The population of this study was Addis Ababa handball project coaches, trainees sport administrative bodies. The total numbers of handball project trainees, coaches and sport administrative bodies form three sub cities were 292. Among these 250 were trainees, 10 were coaches, and the rest 32 were sport administrative officials.

Sample Size and Sampling Technique

The study used census for coaches and administration officials and stratified sampling for trainees. Stratified sampling is an alternative method to systematic sampling and preferable where the sampling frame contains distinct (heterogeneous) population.[8] The size of the sample is calculated by using Slovin's formula[9] which is written as:

$$n = \frac{N}{(1+Ne^2)}$$

Where; n=sample size, N=total population, and e=error of tolerance.

By using this formula with confidence level of 95% (0.05), the sample size was 92. Based on this formula, the sample frame of trainees were 50. Census method is that method of statistical enumeration where all members of the population were studied.[8] Accordingly, all coaches (10), and handball federation officials (32) were used as a sample because it is important to get first-hand information about the research problem, since they have a direct relation and experience about the issues.

Source of Data and Data Collection Instrument

For present research work the primary and secondary data were used. Primary source of data was collected from trainees', coaches, supervisors and sport administrative bodies. Secondary source of data was gathered from documents, books, journals, articles, web sites and research papers related to the study. The instruments used for data collection was questionnaires, and field observation. Both qualitative and quantitative data collecting instrument was sate in the data collecting process.

RESULTS AND DISCUSSION

Based on the Table 1 of standardized training court, safety and maintenance of the training and competition court, 75% (69) of respondents responded were disagree, whereas 25% (23) of respondents replied strongly disagreed on the practice and competition areas are safe, regularly inspected and maintained. Based on the above data, most project sites lacked suitable and safe training court. As explained by Jesse et al,[10] when facilities are lacking as in innumerable projects then training is held in uncomfortable field. Such places limit the program and when facilities are lacking the trainees do not learn the skill and coordination that is essential for their development. On item 2 of Table 1, availability of sport equipment and training materials, 59.9% (55) were disagreed, 35.8% (33) strongly agreed and 4.3% (4) were agreed. This indicated that the availabilities of sport equipment and materials were inadequate and those finding also supports the previous study of Tesfay.[11] As Jeffs[12] explained that; scarcity of sport materials strongly affects the project training. In addition, the availability of sport facilities and equipment's has a tremendous effect on the development and popularly of a given sport. If the facilities and equipment's are available in sufficient manner it is too easy to produce a number of outstanding players from projects of handball and they will

Table 1. *Response of Coaches, Administrative Officials and Trainees on Facility and Equipment*

S. No.	Items	Strongly Agree		Agree		Neither Agree Nor Disagree		Disagree		Strongly Disagree	
		No.	%	No.	%	No.	%	No.	%	No.	%
1	The training and competition areas are standardized, safe, inspected regularly and maintained	-	-	-	-	-	-	69	75	23	25
2	Availability of sport wear, equipment and training materials (ball, cone, whistle…	-	-	4	4.3	-	-	55	59.9	33	35.8
3	Emergency medical forms, first-aid supplies and personnel are available and easily accessible	-	-	8	8.7	-	-	45	48.9	39	42.4

show highest performance at national even international level.[13,14] Regarding on item 3 of Table 1, 23.8% (8) of respondents agree on the availability of emergency medical forms, first aid kit, 48.9% (45) were responded disagree and 42.4% (39) were replied strongly disagreed on the availability of these first aid materials. This result shows there is no first aid access in the project center and it affects the training program. However, teams must have access to a first-aid kit at all competitions, trainings, clinics and other sporting functions.[15]

As depicted in Table 2, the developments pathways are provided for talents athletes and coaches to pursue careers at higher level 60.9% (56) were agree, 17.4% (16) of respondents replied neither agree nor disagree and 21.7% (20) replied disagree. This shows there is good development pathways provided for talented athletes to select for sub city, regional competition and for club level.[16,17] Regarding to item 2 of Table 2, on the scouting of trainees, 30.5% (28) and 47.8% (44) of the respondent about trainees scouting system responded that strongly disagree and agree consecutively. The rest of 21.75% (20) respondents disagreed. This implies that athlete identification system[18] had not modern that is way it affects the coaching program. As Addis Ababa handball federation[19] stated that, when selecting youths for project training; study the age, family status, health condition, body weight, level of physical fitness components, previous experience, etc. As indicated in the above table of item 3, on the number and length of practices, and contests (competition) appropriate for the age group, 71.7% (66) of respondents were replied disagree, and the rest of 28.7% (26) respondents were replied strongly disagreed. This shows that the time allotment for each training session was not enough; in addition lack of performance evaluation and friendly games for each age category and these may lead the failure of handball development.[20,21] On the item of development of fair play, teamwork and sportsmanship with having fun, 39.1% (36) of respondents replied strongly agree and the rest 60.9% (56) of respondents were agreed. This concludes that, the training program advocates code of ethics and coordination of teamwork and the responses supported by Zinabu.[22]

Regarding on item 1 of the above table, families support of the program 9.7% (9) respondents disagreed, 8.7% (8) neither agreed nor disagreed, 61.9% (57) agreed and the rest of 19.6% (18) responded strongly agree. This result indicates the support of trainees' family is too low. As Canada Sport Federation[23] explained that, "*coach must work cooperatively with parents to provide good experience of youngsters*". Regarding on ratio of coaches to participants, 3.3% (3) of coaches and the administrative personnel responded disagree, 72.8% (67) of respondents agreed and the rest of 23.9%

Table 2. *Responses of Coaches, Administrative Officials and Trainees about Scouting and Developmental Pathways of Coaches and Trainees*

S. No.	Items	Strongly Agree		Agree		Neither Agree Nor Disagree		Disagree		Strongly Disagree	
		No.	%	No.	%	No.	%	No.	%	No.	%
1	Development pathways are provided for talented athletes and coaches to pursue careers at a higher level	-	-	56	60.9	16	17.4	20	21.7	-	-
2	Trainees selection (scouting system) is scientific and via the help of medical staff	28	30.5	44	47.8	-	-	20	21.7		
3	The number and length of practices,and contests (competition) appropriate for the age group	-	-	-	-	-	-	66	71.7	26	28.3
4	The training increases development of fair play, teamwork and sportsmanship with having fun	36	39.1	56	60.9	-	-	-	-	-	-

Table 3. *Response of Coaches and Administrative Officials on Coordination, Support and Communication*

S. No.	Items	Strongly Agree		Agree		Neither Agree Nor Disagree		Disagree		Strongly Disagree	
		No.	%	No.	%	No.	%	No.	%	No.	%
1	The trainee families support and follow the training program	-	-	66	71.7	-	-	26	28.3	-	-
2	The ratio of coaches to trainee is appropriate for providing adequate instruction, supervision and safety always	22	23.9	67	72.8	-	-	3	3.3	-	-
3	The program has social network, cultural value and economic benefit	-	-	17	18.5	27	29.3	48	52.2	-	-
4	Communication between coaches, parents and officials	20	21.7	56	60.9	-	-	16	17.4	-	-
5	Follow up and supervision of program by supervisors, sport officials	-	-	39	42.4	8	8.7	45	48.9	-	-

(22) replied strongly agree. This shows that the coach trainee ratio is not appropriate and difficult to manage, instruct and correct the trainees. According to Knopp and Leonhard cited in Endrias Ferenji[24] stated that; the type of program, teaching methods and available facilities affected by the size of the class. On the item 3 of Table 3, social, cultural and economic benefit of youth handball training program, 18.5% (17) respondents agreed, 52.2% (48) replied disagree and the rest 29.3% (27) neither agreed nor disagreed. However, sport plays a significant role in the generation of economic activity and in the provision of services to spectators, participants, communities, athletes, coaches, administrators and the corporate sector.[6,25] Regarding to item 4 of Table 3, 21.7% (20) of respondents responded that strongly agree about the communication between coach, parent and officials, 60.9% 56) of them is agree, 17.4% (16) of the rest responded disagree. This indicates that there is lack of communication between coaches, families and officials. However, effective working relation can be realized by good communication between administrator, coaches and parents facilitated by effective managers.[26,27] Regarding on item 5 of above table, about follow-up and supervision of program by supervisors, sport officials, 39.1% (36) of respondents replied that agree on evaluation and supervision. 8.7% (8) were replied neither agree nor disagree and 48.9% (45) respondents were disagreeing. This implies that there is lack in continuous supervision and follow-up of the training program. As Côté[28] stated robust monitoring and evaluation can contribute to the accumulation of knowledge about 'best practice', leading to an increase in the effectiveness of sports development work.

Based on the Table 4 of item 1, 23.8% (10) respondents replied strongly agree on that of budgeting is a cause, and 76.2% (32) respondents agreed for this case. This indicates 100% of respondents were agreed on budgeting problem is major causes in implementing training program. As with all other endeavors, finance and sponsorship are vital requirements. The costs associated with sports continue to hinder its development and serves to discourage widespread participation. According to Mills, cited by Kelbessa,[29] every organization needs financial support to deliver its programs and projects. Regarding to collaborative work between education bureau and sport bureau, 45.3% (19) of respondents responded that strongly agreed, and 21% (50) of them were agree, 2% (4.7) of the rest responded disagree. As Ministry of Youth and Sport[30] stated, the project training program does not work lonely without the coordination and collaborative work between each sectors of ministry of youth and sport and ministry of education from higher level to school level. Because the project is run mostly in school and trainees almost students especially education sectors play crucial role to implement the junior and youth sport project training. In addition to that, the linkage between youth federations and other governmental and non-governmental sectors also important. On item 3, trainees families awareness about youth sport training program, 15% (35.7) agree, and 64.3% (27) were disagree. These shows, trainee families weren't aware to the sport program. The Coaching Manualcited by Dawit[31] explained that; "*the overall support of parents can be gained through understanding and communication, but if the training process ignores parent, there will be resistance and affect the training program*".

Table 5 shows about the quality of coaches. In relation to the regular and immediate feedback during session for players, 16.3% (15) were replied disagree, 20.6% (19) replied neither agree nor disagree, and the rest of 63.1% (58) respondents agreed on the coach give regular and immediate feedback during session for players. About the approach of coaches, 54.3% (50) respondents replied disagree, 24% (22) replied agree and the rest of 21.7% (20) strongly agreed. Regarding to the conflict handling of coaches, 67.4% (62) respondents were agreed and 32.6% (30) replied disagree on the coaches' conflict handling skills. In relation to the coach's quality of motivational skill, 38% (35) respondents agree and 31.5% (29) of respondent's neither agree nor disagree on this issue and the rest of 30.5% (28) replies disagree. Regarding on item 5, 43.5% (40) respondents replied agree on coach's listen and value others opinion, 40.2% (37) were disagreed and the rest of 16.3% (15) are strongly disagree on coach's listening and giving value for others opinion. This data shows most handball project coaches have good communication and relationship with players and concerned body, and this increases the program effectiveness. The success of any coach perhaps every level of competition, is determined by his ability to effectively communicate with athletes in a mutually supporting manner. In addition, coaches may be knowledgeable and highly organized, but without open communication skills, these attributes may never be reflected in the performance of their athletes.[32] Regarding on item 6, 65.2% (60) respondents replied agree, and the rest 33.8% (32) replied disagree. Regarding on item 7, 46.7% (43) respondents agreed on the coaches' use of training time and punctuality, 40.2% (37) replied disagree and the rest of them 13.1% (12) replied strongly disagree about coaches' punctuality. Regarding on item 8, 38% (35) respondents replied agree on the coaches' time usage and the rest of them 62% (57) respondents replied disagree on the coaches' adequate demonstration, and explanation skill. Regarding to item 9, 29.3% (27) were agreed, 52.2% (48) replied disagree and the rest 18.5%

Table 4. *Response of Respondents on the Causes that Challenge Handball Project Coaching*

S. No.	Items	Strongly Agree		Agree		Neither Agree Nor Disagree		Disagree		Strongly Disagree	
		No.	%	No.	%	No.	%	No.	%	No.	%
1	Budget and financing for sport sector is very little	10	23.8	32	76.2	-	-	-	-	-	-
2	Lack of collaboration work between education bureau and sport bureau	19	45.3	21	50	-	-	2	4.7	-	-
3	Awareness of the community about youth sport training program	-	-	15	35.7			27	64.3	-	-

Table 5. *Analysis of Results on Coach's Quality*

S. No.	Items	Strongly Agree		Agree		Neither Agree Nor Disagree		Disagree		Strongly Disagree	
		No.	%	No.	%	No.	%	No.	%	No.	%
Coaches' communication and relationship											
1	The coach gives regular and immediate feedback during session for players	-	-	58	63.1	19	20.6	15	16.3	-	-
2	He/she can easily approach his players about personal problems if might have	20	21.7	22	24	-	-	50	54.3	-	-
3	The team does not have many conflicts; if any, the coach can handle problems effectively	-	-	62	67.4	-	-	30	32.6	-	-
4	He/she can to inspire his players and understand their motivational forces that stimulate their participation.	-	-	35	38	29	31.5	28	30.5	-	-
5	He/she listens and value others opinion	-	-	40	43.5	-	-	37	40.2	15	16.3
Coaches' leadership traits and practice											
6	Coach has confidence in his ability to coach during training and competition	-	-	60	65.2	-	-	32	33.8	-	-
7	The coach is punctual in training time and time use properly	-	-	43	46.7	-	-	37	40.2	12	13.1
8	The coach can demonstrate adequately, that goes hand in hand with proper explanation at the same time	-	-	57	62	-	-	35	38	-	-
9	The coach measures and evaluates trainees performance (fitness, technique and tactics)	-	-	27	29.3	17	18.5	48	52.2	-	-

Table 6. *Field Observation Checklist*

S. No.	No.	Very Good	Good	Poor	Adequate	Inadequate	No Existence
1	Training manual usage			√			
2	Preparation of training plans			√			
3	Method of demonstrating the training session			√			
4	Coaches portfolio			√			
5	Communication and feedback			√			
6	Training equipment (ball, cone)					√	
7	Sport wear, shoes and kits						√
8	Attendance records		√				
9	Trainees personal profile			√			
10	Standardized training court			√			

(17) respondents responded neither agree nor disagree. This shows that most project coaches have a leadership trait and controlling the practical environment. But in use of time and athlete's performance evaluation, they are not good. They have basic knowledge of the sport skills what teaches, flexible and ability make training easy to trainees, use time wisely and has confidence in his ability to coach during training and competition, a quality of organized and plan for contingency and can demonstrate the contentfor example, came up with the following inventory that describes a good coach: Knowledge about skills, punctual, adventurous, has a loud voice, flexible.[33-36]

Analysis of Field Observation

The researcher observed 10 Addis Ababa youth handball project centers. The total registered trainees were 250. During three term observation, the average trainees who actively engage in trainee were 151, which showed 60.4% of registered trainees were observed (Table 6).

Though this is the fact that, as the researcher actual field observation depicted in the above table, accordingly, training manual usage was poor. The training site and its surroundings were not attractive, and the court also not in a standard type. Multiple

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method of training was not applied. Poor preparation of training plans was administered. Training materials were inadequate. In line with this, there was no sport kits supplied for trainees. Due to this deficiency, there were a small number of trainees observed during the training day. The shortages of these materials have a negative impact on the effectiveness of the training process in general and the coaches and the trainees. In addition, trainees and coaches personal profile was not well recorded but the attendance record was yet good. Based on the actual observation, the communication and giving feedback timely was not good.

CONCLUSION

Based on the major findings of the study, the following conclusions were drawn.

• The study found out that forming fruitful organizational process that can contribute to the development of youth handball program. However, lack in communication horizontally relation with the same standard and vertically from up to down and from down to up.

• In line with this, it was proved that coaches did not take coaching course, refreshing and up-to-date training. Due to this, most coaches did not use the manual properly, poor in preparing training plan continuously, lack in communication and timed feedback, recording necessary files as documentation. Hence the number of coaches in the project was not enough; they have been carried out low educational background and have no high coaching certificate.

• Even if the manual was also not prepared based on the training age, sex and fitness level. Hence the goal of training program is not clearly listed on the manual. The time allotment for training is not enough. Besides, sufficient friendly matches and performance evaluation competitions were not organized for each age category. Alike, some talented and promising athletes have been selected to play for high-level.

• The activities and the whole accountabilities were limited to certain sport expertise, and even personalities that were making fewer follow-ups, lack of families and community awareness about program, lack of collaborative work between education center and project coaching program are major causes that hamper the implementation of coaching handball.

• Moreover, due to lack of incentive, unsafe training court, trainees' family's willingness to support, unavailability of sport kit and inappropriate training time, the number of trainees were decreased when compared to registered athletes. And this greatly affects the training program implementation.

RECOMMENDATIONS

Based on the findings of this study, the following are the possible areas of intervention suggested as recommendation.

• National federation of handball should organize technical department in collaboration with surrounding schools of PE teachers to have information about youth's interest and talent for appropriate selection by using talent identification mechanism.

• For the successfulness of the project activities the existence of competitive coaches is paramount important. Regarding this, qualification, skill, competency, and performance-based coaches endorsement should be employed. Refreshment, updating and upgrading coaching courses for coaches and all stakeholders should prepared. In line with this, make a good coordination and communication with medical staffs who dictate the athletes' age *via* scientific method to avoid age eligibility controversy.

• Supervisors should follow-up, monitor the training program and observe the progress with give technical assistance *via* video or other modes.

• National federation and regional federation even if coaches should organize different competitions and friendly matches among project trainees in schools, to evaluate the trainees' progress and bring strong relationships between them. Furthermore, use modern database software for trainees' registration so that may decrease the false age eligibility.

• Coaches should do their work *via* plan. Moreover, coaches should prepare physical, technical, tactical and other check list to evaluate the progress of the trainees. In line with this, data's and profiles as well as other necessary documents should be appropriately recorded.

• Families of trainees', communities, and investors, should improve the condition and maintenance of available facilities and sites, support necessary and sufficient equipment so that they are attractive, healthy and safe for training.

• As project training is milestone to generate new successor players for the club and national team level so that the government should provide sufficient technical and financial assistance to all level of organized sporting organizations.

• In addition to this, national sport governing bodies should design a roadmap to ensure sport as public base and formulate new policies and regulations to establish youth team at club level.

• Specific attention must be given to acquiring and developing resource material such as manuals, coaching kits and electronic aids, which will assist in improving knowledge and advancing the technical skills of sport persons.

Generally, all levels of youth and sport affairs office and handball federations, community, families, coaches, trainees' schools, and physical education teachers must work together to achieve the project objective by designing new structure to work coordinately. In addition to this, it is essential to aware parents by creating different meetings or written material and participate them by organizing different ceremonies, ask to attend families during training time.

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SPORTS AND EXERCISE MEDICINE

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Brief Research Report

Contributions to Global Self-Esteem: Domain Specific Self Perceptions in Athletes *Vs.* Non-Athletes

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ABSTRACT

Objective
The objective of the present study was to examine the influence of social self-concept and physical self-worth on global self-esteem in college athletes compared to their non-competing peers. It was hypothesized that the unique contribution of each variable on self-esteem would be markedly different between the groups.

Methods
In a population of 146 undergraduate students, regression analyses revealed significant relationships between the domain-specific self-perceptions and global self-esteem in both groups. It was determined, however, that athletes and non-athletes differed in the distribution of variance explained by the variables. Specifically, the variance in self-esteem in athletes was attributed exclusively to physical self-worth while non-athletes revealed unique contributions from both social self-concept as well as physical self-worth.

Results and Conclusion
The results of the present study may be meaningful from the perspective of athletic identity and retirement from sport. Further investigation is warranted, both qualitatively and quantitatively, that may assist in developing strategies to ease the transition from participating athlete to non-competitive participation. An additional area of interest may be in examining the relationship between the domain-specific self-perceptions and psychological risk for, and impact of, athletic injury.

Keywords
Self-esteem; Athletes; Social self-concept; Physical self-worth; Non-athletes.

INTRODUCTION

Shavelson et al[1] introduced a hierarchical model of the self-concept that highlights the multiple domains that contribute to the composition of the self. These domains included academic, social, emotional and physical self-concepts, all of which collectively contribute to general descriptions of self. According to Shavelson et al,[1] achievement in specific domains should be positively related to self-conceptions within those domains. The accumulation of self-conceptions, then, comprised the global self-concept. Self-esteem is considered the value that an individual places on their collection of self-conceptions accumulated in those multiple domains of functioning.[2]

Self-esteem research has adopted the hierarchical structure of the Shavelson framework and supports a multidimensional view of self-development. Harter,[3] for example, argued that self-esteem development is unique to the individual's accomplishments and experiences. Research supports this argument as achievements in specific achievement settings have been shown to significantly influence global self-esteem through domain specific paths. Byrne et al,[4] for example, found that academic achievements were significantly related to self-conceptions regarding those achievements in a population of 3rd, 7th and 11th grade students. Similarly, physical activity participation has been shown to positively influence global self-esteem through increases in physical self-worth.[5]

The objective of the present study was to examine contributions to self-esteem in a group of collegiate athletes and to compare them to their non-competing peers. It was expected that both social self-concept and physical self-worth would be significant independent predictors of global self-esteem. However, it was

hypothesized that athletes and non-athletes would display differing patterns of influence on self-esteem based on their experiences in and out of the athletic arena. Specifically, it was expected that the self-esteem of athletes, because of more extensive exposure to achievements in the physical domain, would be more strongly influenced by perceptions of the physical self while that of non-athletes would exhibit a more balanced contribution from both domain specific levels of self-perception.

MATERIALS AND METHODS

Participants

Participants in the investigation were 146 college-aged individuals, 46 of whom were student athletes at the university, enrolled in undergraduate courses at a small liberal arts university in the north-east. This university is designated as a Division II institution by the National Collegiate Athletic Association. There were no criteria for inclusion or exclusion from the investigation. All participants reviewed an informed consent form that was in compliance with the University Institutional Review Board's guidelines for the use of human subjects in research.

Measures

In addition to an extensive demographic questionnaire and exercise history, all participants completed several instruments assessing social, physical, and global self perceptions. Social self-concept was measured using a modified version of the social self-concept scale (SSCS) as developed by Zorich et al.[6] This measure was scored on a five-point Likert type scale with the anchors 1: "strongly disagree" and 5: "strongly agree," and consisted of 28 items that addressed an individual's evaluation of his or her feelings, thoughts and behaviors regarding their social self-perceptions. Sample items included "*people view me as an outgoing, sociable person*" and "*most people view me as having poor social skills.*" Item scores were summed to yield a scale score representing social self-concept. Higher scale scores were representative of those with higher social self-concept. The authors reported high internal consistency for the original instrument (0.95) in a population of 364 college students. Cronbach's alpha was 0.94 for the present sample.

Physical self-worth was measured using the 6-item physical self-worth subscale of the Physical Self-Perceptions Profile (PSPP) as developed by Fox et al.[7] Scored on a four-point Likert type scale with the anchors 1: "not at all true" and 4: "completely true," participants were asked six items that assessed the value that they placed on their physical capabilities. Sample items included "*I am extremely proud of who I am and what I can do physically*," and "*I feel confident in the physical side of myself.*" Item scores were summed to a single score representing physical self-worth. Higher scores were indicative of higher perceived worth for the physical self. Fox et al[7] reported internal consistencies that ranged from 0.81 to 0.92, and test-retest reliability ranging between 0.74 and 0.92 for a 16-day lapse period in multiple samples of college-aged individuals. Cronbach's alpha was 0.88 for the present sample.

Self-esteem was measured using the Rosenberg Self-Esteem (RSE) Scale.[8] The Rosenberg scale is one of the most widely used instruments employed for the assessment of self-esteem. Scored using a four-point Likert type format with the anchors 1: "strongly disagree" and 4: "strongly agree," respondents were asked the extent to which each of ten items was indicative of their global self-perceptions. Sample items include "*I certainly feel useless at times*," and "*on the whole, I am satisfied with myself.*" Items were summed to yield a single scale score representing self-esteem. Higher scores were indicative of greater self-esteem. Fleming et al[9] reported an internal consistency of 0.88 for the Rosenberg scale. Cronbach's alpha was 0.89 for the present sample.

Procedures

Participants were recruited for the study from undergraduate courses and participation was voluntary. Participants reviewed a document highlighting their rights and responsibility as participants in the investigation and then completed a packet of inventories containing a general demographics questionnaire in addition to the measures described previously. Completion and return of the packet served as an indication of consent to participate in the investigation.

Analytical Strategy

Statistical Package for the Social Sciences (SPSS) version 13.0 for Windows was used to examine the relationships of interest. Linear regression was utilized to assess the contributions of physical self-worth and social self-concept on global self-esteem. The following steps were followed to assess the contributions of each domain specific self-perception on global self-esteem. First, physical self-worth was regressed on self-esteem, then both physical self-worth and social self-concept were regressed on self-esteem and the significance of the change in R^2 was analyzed.

RESULTS

Descriptive statistics showed that the population had an average age of 19.4-years and were predominately in their first or second year of undergraduate study (69% freshmen or sophomore standing). The sample was 52.7% female and nearly 90% Caucasian (89.7). Respondents indicated an average of 3.97-days per week of regular activity at a moderate intensity for more than 30-minutes per bout.

Tables 1 and 2 summarize the analysis of study hypotheses for non-athlete and athlete populations. Consistent with hypotheses, both social self-concept and physical self-worth were significant independent predictors of variance in global self-esteem. Furthermore, the contributions of the domain specific self-perceptions on self-esteem were markedly different for athletes compared to non-athletes. These findings are presented in greater detail below.

Multiple regression analysis was used to test if physical self-worth and social self-concept were significant, independent predictors of participants' ratings of self-esteem in the non-athlete

population. Results of the regression indicated that physical self-worth explained 36.2% of the variance (R^2=0.362, F(1,98)=54.92, p<0.01). Results also indicated that social self-concept explained 23.8% (R^2=0.238, F(1.99)=30.57, p<0.01). When considered together, results of the regression revealed that both physical self-worth and social self-concept explained 48% of the variance (R^2=0.483, F(2.98)=44.80, p<0.01). As hypothesized, it was also determined that each domain specific measure contributed uniquely to the total variance in self-esteem scores. It was found that physical self-worth significantly predicted self-esteem (β=0.51, p<0.01), as did social self-concept (β=0.36, p<0.01).

Table 1. *Summary of Hierarchical Regression Analysis for Variables Predicting Self Esteem in Non-Athletes (N=100)*

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Physical Self-Worth	0.975	0.132	0.601	0.829	0.123	0.511
Social Self-Concept				0.149	0.031	0.360
R^2		0.362			0.483	
F for change in R^2					4.743*	

*SE: Self-Esteem. *indicates significance*

Multiple regression analysis was then used to test if physical self-worth and social self-concept were significant, independent predictors of participants' ratings of self-esteem in the athlete population. Results of the regression indicated that physical self-worth explained 41.2% of the variance (R^2=0.412, F(1,44)=30.10, p<0.01). Results also indicated that social self-concept explained nearly 29% (R^2=0.288, F(1,45)=17.76, p<0.01). When considered together, results of the regression revealed that both physical self-worth and social self-concept explained 42% of the variance (R^2=0.421, F(2,44)=15.242, p<0.01). As hypothesized, it was found that physical self-worth significantly predicted self-esteem (β=0.539, p<0.01), whereas social self-concept did not (β=0.14, p=0.428).

Table 2. *Summary of Hierarchical Regression Analysis for Variables Predicting Self Esteem in Athletes (N=46)*

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Physical Self-Worth	1.112	0.203	0.642	0.934	0.302	0.539
Social Self-Concept				0.061	0.077	0.140
R^2		0.412			0.421	
F for change in R^2					0.800	

SE: Self-Esteem.

DISCUSSION

The objective of this investigation was to examine the unique contributions to global self-esteem in a population of Division II college athletes compared to their non-competing peers. It was expected, based primarily on the achievements and experiences distinctive to the college athlete population, that patterns by which domain specific self-perceptions influenced global self-esteem would be markedly different between the groups. Consistent with study hypotheses, it was determined that athletes used primarily physical self-perception information as their source of self-esteem while the non-athlete peers exhibited a more balanced pattern of influence.

It is important to note that the amount of variance explained by physical self-worth was consistent with other studies of this kind. Sonstroem et al,[5] for example, in their original expansion of the Exercise-Self-Esteem Model[2] were able to attribute 32.8% of the variance in self-esteem to physical self-worth in a population of 216 female aerobics participants. Additionally, while the model tested accounted for 42% and 49% of the variance in self-esteem, it is recognized that there is a room for improvement as over half of the variance is yet to be explained. It will be important for future studies to incorporate other aspects of the self in examinations of domain specific contributions to self-esteem.

As Shavelson et al[1] suggested, multiple facets must be addressed in fully understanding the development of the global picture of the self. Yet, existing studies examining the relationships in physical activity participants, including athletes, have focused almost entirely on self-esteem as a function of physical self perceptions.[2,5] Investigations of the role of sport participation and self-concept in other domains in the Shavelson framework are warranted, specifically, the academic and emotional self-concepts. Previous research has established a relationship between physical activity participation and several other psychological outcomes such as depression,[10] perceived quality of life[11] and positive well-being.[12] Given these established relationships, it is conceivable that sport participation may influence self-esteem through the emotional self-concept as a function of the psychological benefits derived from participation. Similarly, being that the participants in the present investigation were student-athletes, it is expected that some of the variance in their self-esteem may also be attributed to the esteem garnered from their academic pursuits. Expansions of the present investigation based on the above hypotheses would provide an even broader understanding of the impact of athletic participation on all facets of self-esteem development.

Design limitations in the present investigation are also recognized. The sample size, while small, was representative of the student body at the university as a whole. It will be necessary to examine the associations of interest using additional participants as well as participants at varying levels of athletic participation, recreational *vs.* organized, for example. Additionally, the athlete population in the present study consisted primarily of self or partially funded individuals at the Division II level of competition. These relationships also warrant investigation at higher levels of participation such as the major Division I level. Similarly, while there is a great deal of research investigating various psychological variables in scholarship student-athletes, investigations comparing scholarship and non-scholarship athletes is surprisingly scarce. It

would be interesting, and necessary, to examine the relationships of interest in the present study in fully funded student athletes *vs.* non or partial scholarship teammates, as opposed to non-athletes in general. Scholarship status has been shown to influence intrinsic motivation.[13] It is reasonable to suggest that the relative contributions to self-esteem in scholarship athletes, some of whom may be using their college scholarship as a vehicle to reach the professional levels, may be markedly different than those participating with an understanding that professional participation may not be in their future.

CONCLUSION

Not withstanding, results of the investigation may be meaningful from the perspective of athletic identity, specifically with reference to inevitable retirement from sport, whether due to injury, personal choice or exhaustion of eligibility. Much has been written about the issues that athletes face upon retirement from sport with much of this research concluding that athletes must be proactive in the diminishment of their athletic identity in preparation for the transition to non competition. Lally[14] for example, in a longitudinal study of 3 male and 3 female university student athletes, concluded that it was necessary for athletes to begin redefining their self-concept well in advance of retirement in order to experience less disruption upon transition to leaving sport. Similarly, Webb et al[15] found that higher athletic identity was related to greater retirement difficulties in a population of 93 high school, college, and professional athletes. It will be necessary for future investigations of the relationships described in the present study to employ qualitative methods in determining whether athletes whose self-esteem centers primarily on their physical self-perceptions face future difficulty upon pending or actual retirement from competitive participation.

An additional area of interest may be related to the psychological impact of athletic injury. The psychosocial factors related to injury occurrence, efficiency of rehabilitation and ease of transition back to competition have received a well spring of interest over the last several decades. Research has determined that the extent to which an individual identifies as an athlete plays a critical role in how they react to experiencing injury,[16] how they approach their rehabilitation,[17] and their emotional states through the rehabilitation and return to play process. It will be interesting to examine whether development of the whole person might be of benefit in preparing for the psychological impact of injury.

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SPORTS AND EXERCISE MEDICINE

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Systematic Review

The Roles of Physical Activity in Preventing Type 2 Diabetes Mellitus: The Implications for Sub-Saharan Africa

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ABSTRACT

Background
Diabetes mellitus is a chronic metabolic disorder characterized by hyperglycaemia which is due to reduced insulin secretion and/or action. It has 6 sub-classes but type 2 is the most common. The prevalence of type 2 diabetes is rising at a very high rate in the sub-Saharan Africa region. Prevention is however better than cure and there are multiple pieces of evidence of the highest level that type 2 diabetes is preventable. Prevention of type 2 diabetes is looked at from the perspectives of primary, secondary, tertiary and quaternary prevention.

Methods
Measures that have been documented in the literature that can be adopted in the prevention of diabetes include lifestyle modification, pharmacotherapy and surgical interventions. Lifestyle modification is the most commonly reported measure and physical activity is a central focus in lifestyle modification. Physical activity refers to all body movements that lead to expenditure of energy above the resting level. Exercise is a structured and monitored subset of physical activity. Physical activity has been documented to help in the primordial prevention of type 2 diabetes for children born to a woman with gestational diabetes. It helps in modifying risk factors for diabetes such as obesity, dyslipidaemia and high blood pressure.

Conclusion
It is also valuable for secondary prevention of diabetes by modifying risk factors such as obesity, hypertension, excess calorie intake and lipids. Physical activity plays a central role in the management of a patient diagnosed with diabetes at the level of secondary prevention. Effective rehabilitation of patients with type 2 diabetes who have suffered macrovascular complications would constitute a tertiary level of prevention. Since physical activity is an effective, affordable and available form of preventing type 2 diabetes sub-Saharan Africa where the population has limited resources can leverage on its cost-effectiveness. This will help to improve longevity and improve the quality of life of people and save scarce resources in the region.

Keywords
Physical activity; Type 2 diabetes; Prevention; Sub-Saharan Africa.

BACKGROUND

Diabetes mellitus is a chronic metabolic disorder where the central theme is hyperglycaemia due to a defect in insulin secretion and/or action.[1] It is a condition characterized by abnormalities of metabolism of carbohydrates, lipids and proteins. In the latest World Health Organization (WHO) classification, diabetes mellitus is categorized into type 1 diabetes, type 2 diabetes, hybrid type of diabetes, hyperglycaemia first detected in pregnancy, other specific types of diabetes and the unclassified type.[2]

According to recent statistics from the International Diabetes Federation (IDF), over 400 million individuals are living with diabetes and about 90% of this is accounted for by type 2 diabetes, thereby making it the most common type of diabetes.[3] There is an upsurge in the prevalence of type 2 diabetes mellitus due to the

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rising prevalence of obesity, adoption of western lifestyles and increased life expectancy due to the benefits of intensified efforts to combat infectious diseases in the region.[4] The sub-Saharan African region was predicted to witness the highest percentage increase in diabetes incidence than any other region in the world.[3] Therefore, all hands must be on deck to prevent the situation from becoming worse.

Lifestyle modification is the most commonly documented modality of preventing progression of impaired glucose tolerance to type 2 diabetes.[5] Although, pharmacological and surgical therapies have also been documented as means of preventing progression of prediabetes to diabetes but lifestyle modifications remain a key approach.[5] These lifestyle modifications include weight loss, physical activity, dietary modification, consumption of fruits and vegetables and avoidance of excessive alcohol intake.[5] Physical activity remains a central focus in preventing diabetes, especially in sub-Saharan Africa where the prevalence of diabetes is expected to rise dramatically.

Physical activity involves to all forms of bodily movement that increases energy expenditure higher than the resting state. Exercise, on the other hand, is said to take place when physical activity has been prescribed by exercise experts in a structured manner and efficiently monitored.[6] So, exercise is a subtype of physical activity. Physical activity improves cardiovascular risk profile, assists in weight loss and enhances general well-being.[7] Studies have found out that regular physical activity may prevent or delay type 2 diabetes.[8] WHO categorizes physical activities into work-related, leisure-related and transport-related physical activities.[9] Despite the fact that the prevalence of diabetes is rising rapidly in sub-Saharan Africa, the level of physical activities among adults is decreasing and this may portend a great danger in terms of the burden of diabetes and is complications in the region.[10]

AIM

The aim of this review article is to emphasize the role of physical activity and exercise in preventing diabetes mellitus and to highlight the implications of this preventive measure in sub-Saharan Africa, where the resources to treat are lacking and diabetes prevalence is projected to increase at a dramatic rate in the region.

Relevant search terms such as "*Physical activity to prevent diabetes*", "*type 2 diabetes*", "*prevention*", "*diabetes mellitus in sub-Saharan Africa*", "*prevention of diabet*es" and "*prevention of diabetes in sub-Saharan Africa*" were used to search the biomedical databases as well as the grey literature.

METHODS

The biomedical databases explored were PubMed, Google Scholar, Science Direct and African Journals Online (AJOL). Over 80 *in vitro* studies, animal studies, expert reviews, epidemiologic studies, clinical trials, systematic reviews and meta-analyses were retrieved. The authors independently assessed the retrieved articles, and about 40 studies were selected to be the most relevant to the subject matter.

Physical Activity and Health

Physical inactivity or being sedentary is an extensively documented risk factor for type 2 diabetes, cardiovascular disease, cancer, hypertension and depression.[11] Among the modifiable risk factors for diabetes and cardiovascular disease, physical inactivity has been reported to be the most prevalent.[12] The intensity of physical activity is described in terms of the metabolic equivalent of task (MET) defined as the rate of expending energy when performing a physical activity per body mass in comparison with the same rate of energy expenditure at rest.[13] On the basis of MET, physical activities are divided into three categories, light intensity activities (when MET<3) such as writing and typing, moderate intensity activities (when MET is 3-6) such as sweeping floor or walking at 3 mph and vigorous intensity activities (when MET is >6) such as jogging, bicycling and rope jumping.[13] Generally, physical activity leads to increased glucose uptake by active muscles balanced by hepatic glucose production, with a greater reliance on carbohydrate to fuel muscular activity as intensity increases.

In experimental studies that document the evidence of the benefit of physical activity, most moderate to vigorous physical activities were recreational in developed countries but in sub-Saharan Africa, most moderate to vigorous physical activities were non-recreational (work-related and transport-related physical activities).[14] Studies have shown that non-recreational physical activities do not give the same health benefit as recreational physical activities.[15] Additionally, it has been documented that less time is spent doing moderate to vigorous physical activities in low-income countries such as most of the counties of sub-Saharan Africa when compared with the developed countries.[14] All of these factors suggest that the benefit of physical activity in preventing diabetes may not be effectively utilized in sub-Saharan Africa.

The most common cause of death in diabetes is cardiovascular disease. It has been found that people who are physically active are less likely to die from cardiovascular disease.[16] This is crucial for the individuals in sub-Saharan Africa because the burden of cardiovascular disease is rising rapidly in the region.[17]

Barriers to Physical Activity in Sub-Saharan Africa

Physical inactivity is now regarded as a major risk factor of death in developing countries such as found in sub-Saharan Africa.[18] Despite this fact, the prevalence of physical activity in the same region is low.[18] Rapid urbanization is reported to be partly responsible for dwindling level of physical activity among adults in sub-Saharan Africa.[19] The WHO has recommended moderate intensity physical activity of at least 150-minutes per week for adults but the degree of compliance with the recommendation varies widely in sub-Saharan Africa, with some areas observing compliance rate as low as 46% while in others, especially in the agrarian rural areas, the rate of compliance is as high as 95%.[10]

The most commonly reported barriers to physical activity in sub-Saharan Africa are internal barriers and external barriers[18] Internal barriers have to do with self-motivation, presence or lack of skills and energy, fear of injury, feeling of guilt with regards to

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high calorie consumption and personal conviction on the need for physical activity. Many people in sub-Saharan Africa are not motivated to engage in leisure-related physical activity as they believe that work-related physical activity should suffice.[18] External barriers refer to the other factors such as environmental, lack of facilities for physical activity and exercise and poor socio-economic status. Interestingly, the higher the educational status in sub-Saharan Africa, the higher the risk of physical inactivity.[19] This is thought to be work-related as most people tend to reduce their physical activities once they get white-collar jobs. The implication of this for the sub-Saharan African population is that the cohort of urban-dwelling, white-collar employees who have lower physical activities are the same category with those with the highest risk of developing diabetes and cardiovascular disease due to their western lifestyles.[19]

Concept of Prevention of Disease Using Diabetes Mellitus as an Illustration

'Prevention is better than cure' is a universal principle that is relevant also in the field of diabetology. Diseases have natural history and preventive measures can be undertaken at various phases of the disease. The aim of prevention is to reduce morbidity and mortality at individual level and reduce the burden of disease at the population level. The approaches to prevention can be categorized into primordial, primary, secondary, tertiary and quaternary.[20]

Primordial prevention aims at removing future hazards, determinants and risk factors for a disease. For example, optimal maternal health is considered as a primordial prevention of diabetes for the unborn child, later in life.

Primary prevention seeks to address risk factors to a diseases and halt the onset of the disease. The aim is risk reduction either from avoiding the risk or cushioning the effect of the risk. Primary prevention of diabetes will include activities such as reducing caloric intake, weight loss, ensuring physical activity and stopping smoking. Prevention of prediabetes from becoming diabetes is also considered as a form of primary prevention.[12]

Secondary prevention is targeted at treating the disease at the early stage, preferably at the preclinical stage. It is about prevention of the complications of a full-blown disease and maintaining the health of the individual. Optimal glycemic control, lifestyle modification, good blood pressure control and control of dyslipidaemia are secondary prevention measures in a patient with diabetes.

Tertiary prevention refers to the cushioning of the impact of the diseases. It focuses on improving the quality of care and ensuring satisfactory longevity. Rehabilitation and adjustment to disability are the focus of tertiary prevention measures. In this instance, the attention is on post-amputation patients, patients with diabetic nephropathy and other complications to ensure they get the needed optimal care and to improve their quality of life.

Quaternary prevention is a relatively new concept and concerns medical ethics. It is derived from the principle of *'primum non nocere'* which translates as "*above all, do no harm*".[20] Medical interventions also have potential harmful ethics, quaternary prevention is to prevent unnecessary or unethical interventions that have a high-risk of causing harm rather than help. It also deals with taking responsibility for the limited public resources available for care. Actions must be taken to identify and avoid 'over medicalization' of patients. With this approach for example, a diabetic patient with limited life expectancy should not be a candidate for tight glycemic control with multiple daily insulin injection especially where medical care is out of pocket.

Physical Activity and Primordial Prevention of Type 2 Diabetes

Primordial prevention of type 2 diabetes is well-represented in provision of optimal care for women with gestational diabetes mellitus (GDM) because both the mother and the baby are at increased risk of type 2 diabetes later.[21] Gestational diabetes mellitus is defined as any degree of glucose intolerance first detected at pregnancy.[2] Coincidentally, the prevalence of GDM is high and is still rising in sub-Saharan Africa.[22] So, this has tremendous implication in sub-Saharan Africa considering that the obstetric care is presently sub-optimal.

The treatment of GDM is lifestyle modification and central to lifestyle modification is physical activity and exercise. Physical activity has been found to improve insulin resistance and reduces the risk of both the mother and the baby of developing type 2 diabetes later in life.[23] Physical activity can increase energy expenditure thereby helping to control the weight. It can also reduce stress and stress-induced food intake.[24] Physical activities also regulate the secretion and activities of certain hormones such as ghrelin and leptin thereby regulating eating behaviours.[24]

Compared with other preventive measures, physical activity is cheap, easy to use and safe. The fact that physical activity is cheap and does not require any special education makes it an acceptable and potentially effective preventive measure for pregnant women in sub-Saharan Africa where the majority are living in rural areas and have low educational status and financial resources. However, a recent study done of physical activity among market women reported that pregnant women would rather wait for postnatal period because of the fear of having abortion in the first trimester and preterm labour in the third trimester.[25] This implies that adequate physical and health education will be required to promote the adoption of physical activity as a preventive measure.

Another approach to primordial prevention of type 2 diabetes using physical activity concerns children, adolescent and young adult health. A Nigerian study reported a high prevalence of type 2 diabetes among young adults. This has been reported in many other sub-Saharan African countries.[26] This is thought to be partly due to rising prevalence of childhood and adolescent obesity and physical inactivity in the region.[27] Promoting physical activity among children, adolescent and young adult is a cost-effective primordial prevention of type 2 diabetes mellitus.[28] A study conducted in South Africa identified some barriers to physical activity among adolescents namely poverty, perceived benefits of physical activity, lack of physical and health education, demographic factors and poor infrastructure.[28]

Physical Activity and Primary Prevention of Type 2 Diabetes

Primary prevention of type 2 diabetes concerns addressing the risk factors before the onset of the disease. Some of the modifiable risk factors include obesity, excessive calorie intake, physical inactivity, hypertension, dyslipidemia, smoking and excessive alcohol intake. Physical activity can be classified on the basis of the muscles involved and the aim of the activity.[29] In aerobic exercise, there is repeated movement of large muscle groups and examples include walking, jogging and swimming. Resistance exercise aims to develop the bulk and strength of specific muscle groups and a good example is weight lifting. Flexibility exercise targets movement across joints and balance exercise seeks to prevent falls.

Moderate to vigorous intensity physical activity has been documented not only to prevent type 2 diabetes directly but to also prevent it indirectly by reducing other modifiable risk factors such as obesity, dyslipidaemia and hypertension.[6] The implication of this to the sub-Saharan Africa population is that the other modifiable factors that are improved by physical activity namely, obesity, dyslipidaemia and hypertension are highly prevalent in the subregion. Therefore, the effect of physical activity on the prevention of type 2 diabetes is likely to be greater in sub-Saharan Africa. Internet-based interventions to promote physical activity such as internet-based physical activity coaching, goal setting and feedback as well as conversations with the physical trainer *via* phone or e-mail have been found to be more effective than usual care.[30] This may be a challenge in sub-Saharan Africa, despite its documented effectiveness, because internet facilities are not readily available and where it is available, many uneducated people may not benefit and it may be unaffordable to many people.

Physical Activity and Secondary Prevention of Diabetes

In a newly diagnosed type 2 diabetes patient, lifestyle modification is the backbone of management. There are meta-analyses and multiple randomized studies that point to the effectiveness and affordability of exercise in ensuring optimal glycemic control and preventing complications of diabetes.[31] Regular exercise has been shown to independently improve HbA1c, after adjusting for other factors.[31] Physical activity acts as a secondary prevention approach by reducing weight, improving insulin sensitivity and cardiorespiratory fitness, an independent predictor of mortality.[31] Even without any reduction in body weight, it is still effective in controlling blood glucose when taken with other measures.

For individuals in sub-Saharan Africa, physical activity is cheap and can be adopted as an effective mechanism in controlling blood glucose and other parameters such as lipid profile and blood pressure, hence a crucial role in secondary prevention of diabetes.

Physical Activity and Tertiary Prevention of Diabetes

Physical activity and exercise plays a crucial role in the rehabilitation of diabetic patients who have suffered complications of the disease. Macrovascular complications include stroke, coronary heart disease and peripheral arterial disease while microvascular complications include neuropathy, nephropathy and retinopathy. Physical activity and exercise have been found to improve cardiorespiratory fitness, strength and stability in post-stroke patients. It has also been documented to improve cognitive function, mood and general well-being. It has also been shown to reduce mortality and improve the quality of life.[32] Ensuring adequate physical activity, post-myocardial infarction has been shown to be associated with reduced hospitalization, earlier mobilization and improved working capacity.[33] Cardiorespiratory fitness is enhanced and patient can return to work. The relevance to patients in sub-Sahara Africa is that the physical activity-based rehabilitation ensures early return to work so that they can earn a living, as patients often pay out of pocket and may already be in debt following treatment for the stroke or myocardial infarction.

Physical activity has also been found to be beneficial in diabetes patients with peripheral arterial disease. Physical activity improves the walk time before onset of pain, enhance muscular function and vascular supply.[34] It has also been associated with lower risk of limb amputation among patients with diabetes.[34] Amputation is associated with reduced employability so, in sub-Saharan Africa where the basal level of unemployment is high, any effort, including physical activity, to preserve the limb is of enormous importance.

CONCLUSION

The prevalence of type 2 diabetes mellitus in sub-Sahara Africa is high and it keeps rising. However, there are multiple piec es of evidence that type 2 diabetes is preventable. Prevention is categorized into primordial, primary, secondary, tertiary and quaternary prevention. The documented measures of preventing type 2 diabetes are lifestyle modification, pharmacotherapy or surgery.

Central to the concept of lifestyle modification is physical activity which is any degree of body movement that leads to energy expenditure. A structured, prescribed and monitored subtype of physical activity is exercise. Physical activity have been shown extensively to have a role to play in the primordial, primary, secondary and tertiary prevention of type 2 diabetes. Physical activity is effective, affordable and available. The implication of this to the sub-Saharan Africa population is to focus more in adopting exercise and physical activity to reduce the incidence of type 2 diabetes and its burden on the population.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Systematic Review

Adoption of Change: A Systematic Review of the Transtheoretical Model

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ABSTRACT

Introduction
Sedentary lifestyle is a risk factor for life-altering comorbidities. Though the World Health Organization (WHO) and the Centers for Disease Control (CDC) have provided guidelines, 80% of Americans do not get the recommended physical activity (PA) dose per day. Motivation continues to be an important and elusive factor to effect change.

Purpose
Assess the available evidence regarding the application of the transtheoretical model and stages of change theory (TTM-SOC) in the last 10-years to behavior changes for PA.

Methods
Databases including PSYCInfo, ERIC, CINAHL, EBM, DARE, and OVID, were searched with the following key search terms: "Lifestyle Changes" OR "Lifestyle" OR "Active Living" OR "Lifestyle Changes" OR "Physical Activity" OR "Actigraphy" OR "Exercise" OR "Activity Level" AND "Transtheoretical Model" OR "Stages of Change". Seventy-nine studies fit the inclusion criteria and were assessed for quality and validity using the PEDrO scale for experimental studies and the specialist unit for review evidence (SURE) for cohort investigations.

Results
Of the five (5) interventional studies included, none used all four components of the TTM-SOC, namely, stages of change, decisional balance, processes of change and self-efficacy. Observational studies were assessed with eleven (11) classified as observational analytical and nineteen (19) as observational descriptive.

Conclusion
None of the investigations assessed the full TTM-SOC. As such, there can be no definitive conclusions with regard to the effectiveness of stage-matched interventions to promote a change from sedentary lifestyle to adoption of PA. There is a need for more rigorous research to test the application of TTM-SOC with both physiologic and quantitative measures for PA.

Keywords
Systematic review; Transtheoretical model; Stage of change; Physical activity.

BACKGROUND

It is recommended that adults perform at least 2.5-hours of moderate-intensity aerobic exercise or 1.25-hours of vigorous-intensity activity or some combination of both types of exercise in a week.[1] However, on average, less than five percent of adults participate in 30-minutes of physical activity per day.[2] Current evidence suggests that sedentary lifestyles are associated with comorbidities such as obesity, diabetes mellitus and cardiovascular disease,[3] as well as poor health outcomes such as hypertension, hyperlipidemia, stroke, metabolic syndrome, osteoporosis, and certain types of cancers.[4,5] Though the cause of these comorbidi-

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ties are multifactorial, a key component to development of these chronic diseases is lack of physical activity. Conversely, increased physical exercise is correlated with a decreased risk for developing these diseases.[6]

Change is needed. Decades of research into human behavior has expanded our understanding of motivation which is key to any behavior change. Attempts to apply the transtheoretical model and stages of change theory (TTM-SOC) to physical activity, have resulted in non-conclusive findings to support or negate this application of the model.[7,8]

Transtheoretical Model Defined

The TTM-SOC, was created as a compilation of psychological theories to explain behavior change as related to addiction (Prochaska et al). The TTM-SOC initially included the components of stages of change (SOC), decisional balance and processes of change (POC) with self-efficacy (SE) subsequently added. As a motivational theory used to guide interventions for change, the transtheoretical model (TTM) describes the SOC as progressions a person must advance through for the purpose of making an effective behavior change. The SOC consist of precontemplation, contemplation, preparation, action, maintenance and for some behaviors, termination.[9] The TTM purports that each stage aligns with the constructs of decisional balance-the weighing of pros and cons for behavior change; self-efficacy-confidence to make and maintain the change; and processes of change-both cognitive and behavior.[9]

Previous Research

The TTM has been applied with smoking cessation with physicians and other practitioners adopting stage assessment tools and stage matched interventions.[10] Use of the theory has expanded to explain behavior change with regard to exercise and sedentary lifestyles. In a systematic review, authors concluded that there was cautious support for stage matched exercise interventions.[11]

In a systematic review by Bulley et al,[7] (preferred reporting items for systematic reviews and meta-analyses (PRISMA) score=10/27), authors concluded that the accuracy of self-assignment for stages of action or maintenance for physical activity was frequently inconsistent with recommended physical activity guidelines. Furthermore, measurements to assess stages of change for exercise were not found to be valid or standardized, suggesting that more research was needed to investigate the validity of this measure.[7,12]

Validity limitations of the evidence available for the TTM-SOC prior to 2007 include that stage allocation for exercise was linked with self-reported activity, and the physiological parameters (body composition, physical fitness) used are indirect measurements for changes in stage.[7] Additionally, though not direct measures of exercise or physical activity, body mass index, weight and girth measurements were used to assess stage progression. With regard to outcome measures used and construct validity, future investigations require validation of instruments with more rigorous methods.[7,8] The evidence available regarding TTM-based behavior change interventions applied to exercise as moderate physical activity has been focused upon one component, namely, the stages of change, *versus* all four of the components of the model.[7] An additional recommendation is that the full model should be assessed fully/holistically.[8]

There is a need to assess whether evidence during the most recent decade has provided more rigorous evaluation and application of the TTM-SOC with and its full components with regard to physical activity.

PURPOSE

The purpose of this review was to determine how the TTM-SOC has been applied for adoption of physical activity in the last 10-years.

METHODS

Search Strategy

The following databases were searched and accessed May 2017 with updates January 2018 and May 2019: PSYCInfo, ERIC, CINAHL, EBM, DARE, OVID. Key search terms for this literature review included: "Lifestyle Changes" OR "Lifestyle" OR "Active Living" OR "Lifestyle Changes" OR "Physical Activity" OR "Actigraphy" OR "Exercise" OR "Activity Level" AND "Transtheoretical Model" OR "Stages of Change." Inclusion criteria consisted of full text availability, English language, peer reviewed investigations published in the last 10-years, relating to Transtheoretical Model Stages of Change and its application to influence health outcomes *via* physical activity were included in the study. Searching the following additional databases, namely, American Periodicals, ARTbibliographies Modern (ABM), British Periodicals, Digital National Security Archive, ebrary, e-books, GeoRef, PAIS Index, Periodicals Archive Online, ProQuest Dissertations & Theses Global, SciTech Premium Collection, nine (9) articles were found. Of these, all non-peer reviewed findings were omitted.

Inclusion criteria: Investigations that were 1) related to the use of the TTM with physical activity, 2) performed with adults, 3) peer-reviewed, 4) published after 2007, and 5) in the english language (Figure 1).

Initial Review

The search dating 2007-2019 yielded 126 articles. Investigations of reliability and/or validity of model constructs were sequestered from experimental design/randomized controlled trials, though all were organized for further review. Following removal of excluded articles and all subsequent duplicates from overlapping databases, a total of seventy-nine (79) relevant articles were assessed for rigor and inclusion (Figure 1). Articles were organized into two categories: 1) observational (n=61), which included descriptive or analytical studies,and 2) interventional (n=18), consisting of randomized controlled and quasi-experimental studies (Table 1).

Figure 1. *Investigations Assessment Flowchart*

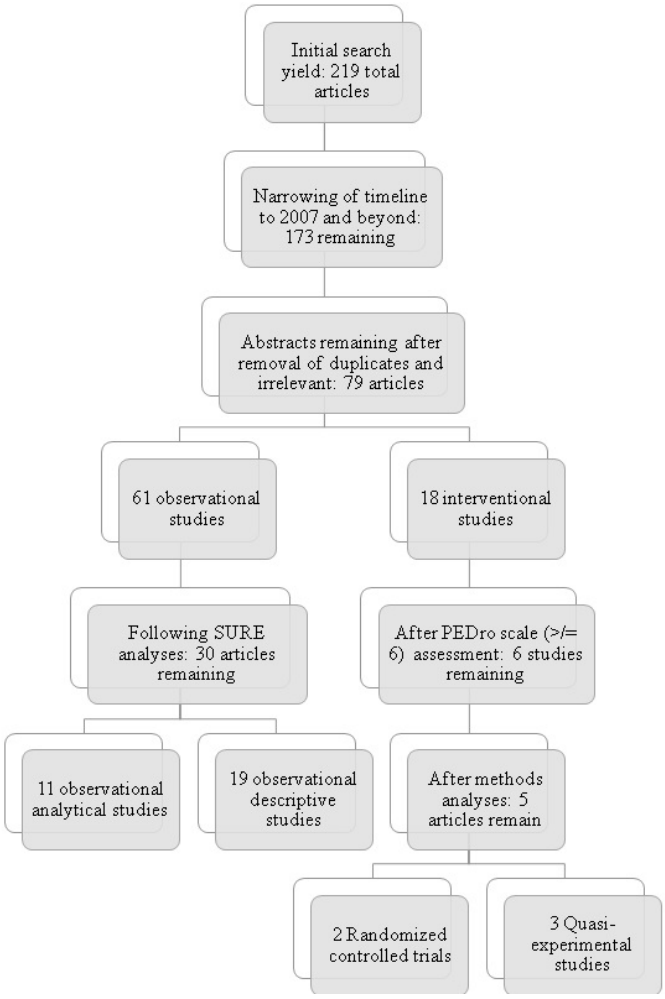

Table 1. *Summary of Interventional Studies*

Author/Year (Design)	Purpose	Study Limitations	Population
Findorff et al[15] (RCT)	To determine whether cross-sectional and longitudinal patterns of exercise adoption reported by older women participating in a randomized trial of an exercise-based fall reduction program would conform to the TTM.	Stage of Change was only variable assessed in control group	Female older adults
Jackson et al[17] (RCT)	To determine behavior change for physical activity in people with type 2 diabetes in differing stages of change, as a result of delivery of TTM exercise intervention.	Does not measure 3 of 4 constructs of TTM*	Adults with Type 2 Diabetes
Fischer et al[16] (Quasi-experimental)	To determine effectiveness of certified personal trainer services in promoting exercise adherence in female traditional-aged college students	Stage specific approach not used	Female, traditional-aged college students
Prochaska et al[18] (Quasi-experimental)	Comparison of initial efficacy of motivational interviewing, online TTM-tailored communications, and brief Health Risk Intervention on 4 health risk factors: inactivity, BMI, stress, smoking	Combined with other theoretical models (Health Risk Intervention, Motivational Interviewing); poor recruitment (25%) and retention (70%) rates; does not measure 4 of 4 constructs of TTM	Adult, university employees
Yang et al[19] (Quasi-experimental)	Application of TTM to test effects of senior elastic band (SEB) exercises on functional fitness in older adults in contemplation, preparation stages of behavioral change	Does not measure 3 of 4 constructs of TTM; significant differences between groups in lower body flexibility at baseline; convenience sampling	Community older adults (65yrs+), who can stand independently with no AD

Measurement Instruments

Investigators applied the PEDro scale[13] to interventional investigations. Inclusion or exclusion was not based upon PEDro scores exclusively, rather, investigations scored > 6 were reviewed for validity of methodology and if strong, were included. Investigations with PEDro scores < 5 were excluded.

The Specialist Unit for Review Evidence[14] checklist, specific to cohort or cross-sectional, non-experimental design investigations was chosen to assess the non-interventional investigations (Figure 2) using recommendations regarding critical appraisal checklists.[15]

RESULTS

Systematic Reviews

No systematic reviews regarding the TTM-SOC and exercise behavior change were found for the past ten years. This lack of synthesis of recent evidence further validates the need for the current systematic review.

Interventional Studies

Of the eighteen (18) interventional studies meeting the inclusion criteria, six (6) scored > 6/11 on the PEDro Scale, so judged 'moderate quality.' Further in-depth analysis of methodology deemed five (5) to be of moderate to high quality evidence and retained. Of these five (5) investigations, three (3) were quasi-experimental and two (2) were randomized controlled trials.[16-20] Of these five (5) articles, two (2) clearly assessed all four constructs of the Transtheoretical Model: self-efficacy, decisional balance, stages of change, and processes of change.[16,17]

Limitations of the intervention studies included that there was a lack of true stage-matching and there was a failure to account for individuals in precontemplation and contemplation

Figure 2. *Cardiff University: SURE Checklist*

Questions to Assist with the Critical Appraisal of Cohort Studies

For all questions below, "yes/no/can't tell"

1. Is the study design clearly stated?
2. Does the study address a clearly focused question? Consider: population; exposure (defined and accurately measured); Comparator/control; outcomes
3. Are the setting, locations, and relevant dates provided? Consider: recruitment period; exposure; follow-up & data collection
4. Were the participants fairly selected? Consider: eligibility criteria; sources & selection of participants; method of follow-up; for matched studies – details of matching criteria and number of exposed or unexposed
5. Are participant characteristics provided? Consider if: sufficient details; a baseline table is included
6. Are the measures of exposures & outcomes appropriate? Consider if the methods of assessment are valid and reliable.
7. Was bias considered? E.g. recall or selection bias
8. Is there a description of how the study size was arrived at?
9. Are the statistical methods well described? Consider: how missing data was handled; were potential sources of bias (confounding factors) controlled for; how loss to follow-up was addressed

   a. Consider threats to internal validity (all 8, including): _____

10. Is information provided on participant flow? Consider if following provided: flow diagram; numbers of participants at each stage; details of drop-outs; details of missing participant data; follow-up time summarized; numbers of outcome events
11. Are the results well described? Consider if: effect sizes, confidence intervals/standard deviations provided; the conclusions are the same in the abstract and full text
12. Is any sponsorship/conflict of interest reported?
13. Finally…did the authors identify any limitations and, if so, are they captured above?

**Specialist Unit for Review Evidence (SURE)*[14]

Table 2. *Summary of Results (Interventional Studies): Stages of Change*

Stage of Change		
Author	**Finding**	**Results**
Findorff et al[15] (RCT)	Individuals with TTM intervention demonstrated increased progression through SOC to become exercise adopters	*p* value<0.001 CI, SD, effect size not avail
Jackson et al[17] (RCT)	Individuals receiving exercise consultation interviews demonstrated increased success rates of stage progression versus control group with no consultation	*p* value 0.007 CI, SD, effect size not avail
Fischer et al[16] (Quasi-experimental)	Within-group comparison of stage of exercise change from T1 to T2 was significant for the control group.	*p* value<0.001, α=0.05 CI, SD, effect size not avail
Prochaska et al[18] (Quasi-experimental)	At 6 months, motivational interviewing and TTM-based intervention groups both demonstrated significantly greater proportions of individuals at criteria (exercising moderately 30 minutes/day for at least 5 days/week) for exercise, as compared to health risk intervention only group.*	*p* value≤0.01 CI, SD, effect size not avail
Yang et al[19] (Quasi-experimental)	Participant stages were identified in demographic profiles. Progressions were addressed in article discussion, minimal descriptions.	N/A

**Action phase was singularly assessed in the study Prochaska et al.[18] at follow-up post-intervention. This indicated a greater number of individuals meeting criterion of the action stage versus individuals who did not meet this stage.*

Table 3. *Summary of Results (Interventional Studies): Decisional Balance*

Decisional Balance		
Author	**Finding**	**Results**
Findorff et al[15] (N=272)	No difference among control versus intervention groups	*p*-value>*0.05*
Jackson et al[17] (N=34)	Decisional balance not assessed in this study	N/A
Fischer et al[16] (N=62)	Significant decrease (negative trend) from T1 to T2 for decisional balance among control group in a measure of which the higher the score, the more beneficial the exercise (pros) is perceived to be.	*p*-value 0.002, Effect size 0.60, CI, SD not avail
	No significant decrease (no negative trend) among experimental group with personal training services in a measure of which the higher the score, the more beneficial the exercise (pros) is perceived to be.	*p*-value 0.461 CI, SD not avail
Prochaska et al[18] (N=1400)	Decisional balance not assessed in this study	N/A
Yang et al[19] (N=169)	Decisional balance not assessed in this study	N/A

Table 4. *Summary of Results (Interventional Studies): Processes of Change*

Processes of Change		
Author	**Finding**	**Results**
Findorff et al[15] (N=272)	Increased use of behavioral processes was demonstrated in exercise adopters between T1 and T2	p-*value<0.001*
	Decreased use of cognitive processes was demonstrated in exercise adopters between T1 and T2	*p*-value<0.001
	Individuals who progressed in SOC but were not yet in action (exercise readiness) demonstrated decrease in cognitive scores	*p*-value 0.016
Jackson et al[17] (N=34)	Processes of change not assessed in this study	N/A
Fischer et al[16] (N=62)	Within-group comparison of exercise mediators at T1 and T2 demonstrated significant decrease (negative trend) among control group for cognitive processes	p-value 0.006, t[30]=2.963 Effect size 0.53 CI, SD not avail
	Within-group comparison of exercise mediators at T1 and T2 demonstrated significant decrease (negative trend) among control group for behavioral processes	*p*-value<0.001, t[30]=4.497 Effect size 0.81 CI, SD not avail
	Statistically significant decrease (negative trend) among experimental group with personal training services for behavioral processes	*p*-value 0.25, Effect size 0.43 CI, SD not avail
	No significant decrease (negative trend) for cognitive processes among experimental group with personal training services	*p*-value .281, t[30]=1.099 Effect size 0.20 CI, SD not avail
Prochaska et al[18] (N=1400)	Processes of change not measured in this study	N/A
Yang et al[19] (N=169)	Processes of change not measured in this study	N/A

Table 5. *Summary of Results (Interventional Studies)*

Self Efficacy		
Author	**Finding**	**Results**
-	Self-efficacy was significant predictor of whether a person would become an exercise adopter long-term	*p*-value<0.05, CI 1.04-1.14, SD, effect size not avail
	In comparison of T1 to T2 at post-intervention, self-efficacy scores for exercise adopters decreased	*p*-value 0.43
	In comparison of T1 to T2 at post-intervention, self-efficacy scores for exercise readiness group decreased	*p*-value 0.29 SD, CI, effect size not avail
Jackson et al[17] (N=34)	Self-efficacy not assessed in this study	N/A
Fischer et al[16] (N=62)	Within-group comparison of exercise mediators at T1 and T2 demonstrated significant decrease in scheduling self-efficacy for control group	*p*-value 0.004, Effect size 0.57, CI, SD not avail
	Within-group comparison of exercise mediators at T1 and T2 demonstrated no significant change for task self-efficacy among control group	*p*-value 0.863, Effect size 0.03 CI, SD not avail
	Within-group comparison of exercise mediators at T1 and T2 demonstrated no significant change for coping self efficacy among control group	*p*-value 0.059, Effect size 0.35, CI, SD not avail
	No significant decrease (no negative trend) among experimental group with personal training services for coping self-efficacy, scheduling self efficacy, or task self-efficacy which indicates maintenance or progression in this group.	*p*-value>0.05, CI, SD not avail
Prochaska et al[18] (N=1400)	Processes of change not measured in this study	N/A
Yang et al[19] (N=169)	Processes of change not measured in this study	N/A

Table 6. *Summary of Results (Interventional Studies): PA Outcome Measures*

Outcome Measure of Physical Activity (Objective)		
Author	**Finding**	**Results**
Findorff et al[15] (N=272)	Walking behavior, as measured by daily exercise logs [primary outcome used for categorization of SOC] demonstrated a significant difference for between-group comparison of individuals in experimental group who became exercise adopters more frequently than the control group.	*p*-value<0.01
Jackson et al[17] (N=34)	Among TTM-based intervention, experimental group receiving exercise consultation interviews demonstrated significant change from initial measure in PA levels to 6 weeks	*p*-value<0.01 CI, SD, effect size not avail
	Among TTM-based intervention, experimental group receiving exercise consultation interviews demonstrated significant change in PA levels after 6 weeks as compared to control group PA levels	*p*-value<0.01 No additional values avail
	Significant difference for experimental group duration of PA as compared to control group	p-value<0.05 No additional values avail
Fischer et al[16] (N=62)	Experimental group with personal training services demonstrated significantly more positive pattern of exercise behavior as compared to control group (adherence)	*p*-value 0.028, Contingency coefficient=0.358 CI, SD, effect size not avail
Prochaska et al[18] (N=1400)	Primary outcome measure to meet criterion for physical activity was stage of change. Objective PA not clearly tracked in this study.	N/A
Yang et al[19] (N=169)	Objective PA not tracked in this study.	N/A

Table 7. *Summary of Results (Interventional Studies): Other Outcome Measures*

Outcome Measure		
Author	**Finding**	**Results**
Yang et al[19] (N=169)	With implementation of senior elastic band program, experimental group participants who engaged in the activity demonstrated significant outperformance at all time points (3- and 6-months) versus control group in: lung capacity, cardiopulmonary fitness, upper and lower body flexibility, upper limb muscle power, and lower limb muscle endurance	*p*-value<0.05, Effect size 0.2, CI, SD not avail
	All 6 variables (lung capacity, cardiopulmonary fitness, upper and lower body flexibility, upper limb muscle power, and lower limb muscle endurance) were significant for experimental group in comparison of pre-test and 6 months later at post-test	*p*-value<0.001 CI, SD, effect size not avail
	Among control group with no elastic band exercises, lung capacity changed significantly from pre-test to post-test at 3- and 6-months	*p*-value 0.34, F=3.61, CI, SD, effect size not avail
	Among control group with no elastic band exercises, cardiopulmonary fitness changed significantly from pre-test to post-test at 3- and 6-months	*p*-value<0.001, F=14.91, CI, SD, effect size not avail
Health Risk Factors		
Prochaska et al[18] (N=1400)	At 6 months, TTM and motivational interviewing groups both had significantly greater percentage of participants reaching criterion for effective stress management compared to health risk intervention group	*p*-value<0.01 CI, SD, effect size not avail
	At 6 months, health risk intervention group demonstrated significantly greater number of health behavior risks than motivational interviewing and TTM groups	*p*-value<0.05 CI, SD, effect size not avail

who did not have any intention to take action towards physical activity (Table 1). Though these investigations purported to test movement through the stages of change, none of these studies provided stage-matched interventions to assess cause-effect, nor tightly controlled the intervention. Therefore, identified investigations maintained common limitations regarding the TTM-SOC noted in prior decades regarding application to physical activity (Tables 2-7).

Stages of Change

All five (5) interventional studies reported on the stages of change, four (4) of which utilized some variant of a self-report questionnaire to measure the SOC for exercise.[16-18,20] One (1) remaining study lacked clarity with assessment of the stages, though theexercise SOC appeared to be assigned by the researcher if the participant met a criterion for exercise.[19] Between-stage movement was assessed for exercise SOC among three (3) studies.[16-18] Where regression was noted, one (1) study offered strategies and discussions to overcome the relapse in stages.[16] Data was correlated with its relation to the current SOC in two (2) studies[16,18] and in one (1) study, subjects were categorized into their SOC based on a measured amount of physical activity.[18]

Decisional Balance

Measured in two (2) of the five (5) included studies, decisional balance was assessed for exercise *via* self-report questionnaire.[16,17] In both of these studies, there were longitudinal comparisons of decisional balance scores throughout the study,[16,17] and one (1) of these studies correlated decisional balance with a SOC measurement.[16]

Self-Efficacy

Two (2) studies measured SE, which was assessed *via* self-report questionnaires.[16,17] Longitudinal assessments of SE from baseline to follow-up were included in both of these studies,[16,17] and in one (1) of these, decisional balance was compared with SOC at post-intervention.[16] This study also used data to determine if SE scores at baseline predicted adoption of exercise by post-intervention.[16]

Additionally, three types of SE for task, coping, and scheduling were measured in one (1) study *via* a self-report scale.[17]

Processes of Change

The POC were measured by self-report questionnaire and assessed by two (2) of the five (5) studies included in this review.[16,17] Additionally, included in both studies was a longitudinal comparison of the POC from baseline to follow-up.[16,17]

Quantitative Measures

Objective quantitative data regarding physical activity was collected by three (3) of the five (5) studies in this review.[16,19,20] However, two (2) of these included self-report daily exercise logs,[16,19] and one (1) used functional fitness measures.[20]

Observational Investigations (Descriptive and Analytical)

Sixty-one (61) observational studies, classified as either descriptive or analytical following analyses with the SURE checklist, did not yield high-level evidence and therefore, conclusions could not be derived from their results. Despite this level of evidence, only the studies of low rigor (n=31) were omitted completely from the qualitative aspect of this review. The remaining thirty (30) observational studies were of low to moderate quality, including eleven (11) observational analytical designs and nineteen (19) observational descriptive designs.

Supplemental tables describing populations and diagnoses investigated. A descriptive assessment has been included to meet the aims regarding identification of populations and topics investigated in the past ten (10) years regarding the TTM (Supplemental Table 8 and Supplemental Table 9).

DISCUSSION

Similar to systematic reviews performed before 2008, this review has combined a quantitative and qualitative approach without meta-analysis due to variation in reported outcomes. Lack of measured and reported effect sizes results in an inability to quantitively combine results.[7,8]

Supplemental Table 8. *Summary of Findings (Observational Descriptives of Moderate Quality)*

Author/Year (Study)	Population/Age/Ethnicity Investigated	Diagnoses?	SURE Score*
Dumith et al[22]	Southern Brazil	N/A	12/14
Kim[23]	Korean [college students]	N/A	10/14
Rogers et al[24]	Adult females	Breast cancer	11/14
Basta et al[25]	Adults	HIV-positive	9/14
Dunton et al[26]	Middle-aged/Community dwelling adults/United States	N/A	10/14
Rhodes et al[27]	Employees/Province of Alberta	N/A	14/14
Sørensen et al[28]	Norwegian	N/A	9/14
Cardinal et al[29] (Cohort)	University students/South Korea/United States	N/A	9/14
Cengiz et al[30] (Cross-sectional survey)	University students/Turkey	N/A	10/14
Lutz et al[31] (Longitudinal)	Undergraduate students/female/United States	N/A	11/14
Bezyak et al[32] (Survey)	Adults	Mental illness (including schizophrenia, schizoaffective disorder, bipolar disorder, other mood disorders, and other psychotic disorders)	9/14
Jiang et al[33]	American Indian/Alaska Native adults	Pre-diabetes	10/14
Kosma et al[34] (Longitudinal)	Adults	Physical disabilities (including multiple sclerosis, spinal cord injuries)	
Malone et al[35]	Adults	Physical disabilities and chronic health conditions (Disabilities or chronic conditions considered to be neuromuscular (such as, cerebral palsy, Parkinson's disease, spinal cord injury, stroke, traumatic brain injury), orthopedic (such as amputation, arthritis, lw back pain, scoliosis), cardiovascular or pulmonary (such as COPD, dyslipidemia, heart disease, hypertension) and multiple (combination of 2+ disabilities or chronic conditions)	
Yildirim et al[36]	Turkish /Women in low or high SES neighborhoods	N/A	11/14
Johnson et al[37]	Undergraduate students/ Community volunteers/Adults	N/A	10/14
Colangelo[38]	Women	N/A	12/14
Duan et al[39]	China/Germany/University Students	N/A	11/14
Kaasalainen et al[40]	Finnish/Men/Low fitness	N/A	9/14

*Cardiff University Critical Appraisal Checklist: Specialist Unit for Review Evidence (SURE)[14]

Supplemental Table 9. *Summary of Findings (Observational Analyticals)*

Author/Year (Study)	Population/Age/Ethnicity Investigated	Diagnoses?	Cardiff University Critical Appraisal Checklist: SURE Score*
Lorentzen et al[41]	Adults in suburban districts of Oslo		12/14
Hellsten et al[42]	Underserved/ minority populations/Females		
Paxton et al[43] (Cross-sectional)	Adult women/Hawaii (United States)	N/A	12/14
Dishman et al[44] (Longitudinal; Cohort)	Adults/Hawaii (United States)	N/A	9/14
Lippke et al[45]	"Adults"		9/14
Stoltz et al[46]	Adults in weight loss groups and activities		9/14
Plow et al[47] (Survey)	Adults	Multiple sclerosis	11/14
Fortier et al[48]	Adults	Type 2 diabetes	11/14
Dishman et al[49]	University Students/United States	N/A	9/14
Geller et al[50]	Adult/Hawaii (United States)	N/A	9/14
Bernard et al[51]	University students/France	N/A	13/14

*Cardiff University Critical Appraisal Checklist: Specialist Unit for Review Evidence (SURE)[14]

Of the literature conducted in the last ten-years (2007-2019), five (5) interventional type studies were found to be of adequate methodology and quality for this review. Assessing the results described above, the stages of change is the first construct to be analyzed.

Stages of Change

An accurate and consistent assessment of the stages of change construct is important for a true stage-matched intervention. Two (2) of the five (5) studies assessed SOC *via* means which were unvalidated.[18,19] Two (2) of the remaining studies utilized SOC questionnaires and reported current research on reliability and validity.[16,17] Additionally, one study utilized an exercise status questionnaire utilized in 1997.[20]

Overall, for the SOC construct, quasi-experimental studies and randomized controlled trials, alike have not contributed new data regarding stage changes than had been reported prior to 2007. This appears to be due to failure to appropriately stage-match the interventions based on the TTM. Despite the support to the TTM provided by findings listed above from these studies, conclusions cannot be considered valid because within three (3) of the five (5) studies, the interventions and/or methods of assessment were not appropriate, therefore lacked internal validity.

As has been stated, interventions were not applied as proposed by the TTM-SOC. Only one (1) interventional study demonstrated appropriate, stage-matched measures and yielded moderate quality results and recommendations.[16] Two (2) of the studies claimed to be stage matched, however, their methods and procedures were unclear to delineate that cognitive processes were used in contemplation, and behavioral processes in action and maintenance.[17,18] One (1) of these investigations inappropriately applied an action-phase intervention to all subjects irrespective of the stage to which they were categorized. Specifically, subjects in pre-contemplation, a traditionally cognitive-based phase of the model, were given an action-phase intervention.[18] Furthermore, one (1) study lacked appropriate stage-matching altogether, with one third of the participants in the contemplation stage performing the exercise intervention,[20] rather than receiving interventions to address the cognitive processes needed to move to action.[19] Results from both studies should be taken cautiously, as integrity to the model is questionable. This lack of internal validity limits the overall validity of findings.

Decisional Balance

Decisional balance (DB) was addressed in one (1) randomized controlled trial (RCT) and one (1) quasi-experimental study of the five (5) interventional studies included in this review.[16,17] The first, by Findorff et al, reported no significant difference between a group with TTM-based intervention and control group. This finding is inconsistent with the theoretical basis of decisional balance within the TTM.[16]

Regarding the cumulative recent evidence on decisional balance, little to no support has been shown to favor the construct as it has been proposed with the TTM. Decisional balance has been omitted in trials based on the TTM regarding health behavior change.

Processes of Change

One (1) RCT and one (1) quasi-experimental study measured the POC.[16,17] According to results found in the RCT,[16] exercise adopters demonstrated increased use of behavioral processes and decreased use of cognitive processes, consistent with the TTM and displaying positive support for the POC construct. In this same study by Findorff et al, individuals who progressed in the stages but were not yet in action (exercise readiness), demonstrated decreased cognitive scores.[16] This additional finding supports the

POC construct proposed in the TTM.

Overall, there has been mixed findings between the two intervention studies regarding the POC construct. Findorff et al. measured these processes to be in support of the TTM, whereas findings by Fischer and Bryant did not.[16,17] In a continued trend, this construct also appears to be neglected by researchers when implementing TTM-based interventions for behavior change.

Self-Efficacy

One (1) RCT and one (1) quasi-experimental study in this review measured SE for exercise among their participants.[15,16] The first of these studies found SE to be a significant predictor of whether a person would become an exercise adopter in the long-term.[16] With a comparison between two time periods, the exercise readiness group demonstrated decreased SE at follow-up.[16] Contrary to the TTM, this study also found SE scores for exercise adopters to decrease when measured post-intervention as compared to their prior scores.[16]

Self-efficacy is an additional construct which appears to be inconsistently measured with interventions relating to the transtheoretical model. Based on the literature cited above, recent research has mixed findings which both support and negate the construct within the TTM.

Objective Measures of Physical Activity

Three (3) of the five (5) included interventional studies included subjective assessments of physical activity (PA).[16-18] One (1) additional study appeared to consider the 'action' stage of change as its primary measurement of achieving PA criterion.[19] In one RCT, exercise behavior was exhibited among participants of the experimental group, who became exercise adopters significantly more frequently than the control group.[16] In another RCT, an exercise group receiving exercise consultation interviews as a TTM-based intervention, demonstrated significant change in PA levels from baseline to follow-up at 6-weeks.[18] A significant difference between PA levels was also present when comparing the experimental and control groups, congruent with the TTM.[18]

The summative data of recent years on objective PA measures with TTM-based interventions is directed towards subjective measurements of PA. Positive support for the model has also been demonstrated, with these subjective measurements, with the association between increased PA levels or exercise adoption and a TTM-based intervention.[16,18]

Overarching findings of this review allude to a continued omission of multiple constructs of the TTM with its implementation for exercise behavior change. As was found in the research published by Bulley et al[7] and Hutchinson et al,[8] the TTM continues to be inconsistently tested within interventional studies with failure to achieve a true stage-matched intervention. Furthermore, the SOC construct continues to be the singularly emphasized measure among interventions despite the previous recommendations for holistic/full implementation of the model.

A limitation of this review is due to the limited strength of methodology among the studies investigated. Moderate was the highest quality of evidence available. Significant limitations to some of the investigations reviewed included improper stage-matching interventions, self-report with recall bias and unclear description of methodologies regarding stage matched interventions. Though it is difficult to use every construct of the model due to required increase of sample size as variables are added, the lack of assessment of the entire model, is a limitation of recent TTM-SOC literature.

Objective measures of PA have not been cited as a construct of the TTM-SOC. However, based on the model's recent application for health behavior change, specifically for exercise, there must be impetus to require a measure beyond self-report for PA. The intervention investigations relied solely on self-report instruments requiring recollection of exercise, thus introducing recall bias.[16-19] While Findorff et al[16] utilized daily exercise logs, one (1) study measured exercise *via* questionnaires based on recollection of past events, and one (1) study inferred patterns of PA based on answers in the Stages of Change Scale.[17,18] One investigation by Prochaska et al,[19] was unclear in assessment of frequency and duration of exercise per week, although the authors appeared to consider achievement of the action stage of change for PA (30-minutes of exercise, 5-days per week) to be the equivalent to meeting criterion for that behavior. In a scientific effort to minimize bias, recall bias, and other errors associated with thinking, objective measures such as activity trackers and pedometers are a necessity to increase validity of findings.

CONCLUSION

Evidence added to the TTM-SOC model in the past 10-years does not appear to provide additional guidance for the health practitioner regarding a stage-based approach for PA. It appears that promotion of cognitive process in earlier stages and behavior processes in latter stages, as outlined by the TTM, has neither been negated nor supported.

Holistic assessment of all constructs of the TTM, including SOC, POC, DB, and SE for PA, were limited among the moderate to high quality of evidence, peer-reviewed studies published in the last ten years. As such, there can be no definitive conclusions with regard to the effectiveness of stage-matched interventions to promote a change from sedentary lifestyle to adoption of PA. There is a need for more rigorous research to be performed to test the application of this model for this behavior change and use of physiological and quantitative, measures for PA within future investigations.

Research conducted to-date has assessed behavior change, or adoption of the behavior of PA. Theoretically, the TTM-SOC was designed to explain the cessation of behaviors (Prochaska et al[21]). The application of the TTM-SOC to adoption of PA, appears to bypass cessation and move to adoption. Mechanism must be understood in order to measure and then manage a diagnosis or a process. Therefore, the application of the TTM-SOC to behavior adoption requires more specific investigation, such that the

mechanism of cessation is considered with then the adoption of PA. Only then, would guidance for practitioners be translated with merit from theory to practice.

Therefore, future research is needed with assessment of SOC to cease sedentary lifestyle in addition to the SOC for PA adoption. A true test of the model with stage-matched interventions and use of all constructs must be done for validation with PA.

In an attempt to manage PA lifestyle and PA itself, researchers must devise a method of measurement with high validity and reliability. This should be possible with the current technology available, however, if PA continues as self-assessment, or unassessed, the evidence for the support of the TTM-SOC will remain questionable and of low evidence.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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