ACCURACY OF MOOV NOW™ EXERCISE PERFORMANCE MEASURES IN RECREATIONAL SWIMMERS

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The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Education, with a major in Exercise Science.

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DEDICATION

To the human body, may we never lose our fascination of its ability

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ABSTRACT

Wearable fitness technology has become an increasingly popular tool to measure physical activity levels and performance measures across multiple sports. As more users rely on these devices to measure and report activity, the accuracy of these devices require in-depth study and validation. Traditional validation research of wearable fitness technology assesses devices on elite competitive populations, however as the general population's consumption of these devices expands, it is important to reveal the accuracy of wearable fitness technology on recreational users. The purpose of this study is to assess the accuracy of the Moov Now, a wearable fitness motion sensor, in the detection of total distance swam and number of stroke cycles in a 200m, free-style swim on recreational users.

Forty healthy recreational swimmers successfully completed one 200m, free-style lap swim while wearing the Moov Now. Moov Now recorded total stroke count and total swim distance. Measures were compared to manual counts from recorded real-time video.

A one-sample *t*-test (p = 0.05, 95% CI) revealed no significant difference (p = .442) between the known distance of 200m and total swim distance reported by the Moov Now. On average, however, the Moov Now underestimated swim distance by 1.56%. An Intraclass Correlation Coefficient (ICC) (95% CI) determined the Moov Now stroke count to be moderately accurate (.618) compared to real-time video manual count. Additionally, the Moov Now on average underestimated total stroke count by 4.03%.

Findings from this study suggest that the Moov Now may be a valid and accurate device in measuring total freestyle swim distance but may not be as accurate in detecting freestyle stroke count during a 200m swim when worn a by recreational swimmer.

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CHAPTER 1

INTRODUCTION

Wearable fitness technology has become an increasingly popular tool to measure activity levels and performance measures across multiple sports. As more users rely on these devices to report and measure activity, the accuracy and validity of these devices require in-depth study and validation. The Moov Now^{TM} is a recent addition to the line of available fitness wearables. Since its introduction into the market in 2014, no known research has been published on the innovative device's accuracy, in particular. With more users, particularly general population and recreational sport users, adopting this device into their health and fitness regimen (Canhoto & Arp, 2017), reliability and accuracy research is warranted.

The Moov Now records exercise performance measures of multiple sports including walking, running, swimming, biking, and boxing. Of these performance measures, many of the Moov Now's most impressive and distinct features are included in the tracking of swim activity. The Moov Now Swim Tracker measures stroke rate, stroke count, distance per stroke, stroke type, total distance, number of laps, as well as the timing of laps, turns, and rest periods (MOOV, 2018). While swim metrics in devices (e.g., Garmin *Swim*, Finis *Swimsense*) similar to the Moov Now have been validated, there is no known validation research available to the public on the Moov Now.

Additionally, many of the validation studies conducted on the other fitness wearables swim metrics were administered on elite swim athletes (Ganzevles, Vullings, Beek, Daanen, & Truijens, 2017; Mooney et al., 2017). Such findings may not be parallel when referencing to other populations, in particular recreational swimmers. Recreational swimmers are more likely to execute a swim stroke with form that is lacking in technique in comparison to that of an elite swim athlete. This may lead to inaccurate swim metric reports from the wearable swim technology (Mooney et al., 2017). Furthermore, such fitness wearables may not assess performance measures on a similar system as the Moov Now.

Previous studies examining the accuracy of the swim metrics in wearable technology (e.g., Garmin *Swim*, Finis *Swimsense*) have analyzed features such as distance, stroke type, swim distance, lap time, stroke count, stroke rate, stroke length and average speed (Ganzevles et al., 2017; Mooney et al., 2017). Of these measures, swim distance and stroke count are two of the primary metrics commonly analyzed when assessing swim sensor validity (Beanland, Main, Aisbett, Gastin, & Netto, 2014; Callaway, 2015; Wright & Stager, 2013). These studies, however, focused on elite swimmers and may not serve in providing accurate fitness activity tracking (e.g., distance swam, number of strokes completed) for the typical recreational swimmer. Therefore, it is important to determine whether the Moov Now device is accurate in measuring distance swam and the number of strokes completed when worn by a recreational swimmer.

Purpose of the Study

The purpose of this study was to determine the accuracy of the Moov Now swim metric tracking system on recreational users. Specifically, the accuracy of the Moov Now in detecting 1) total distance swam, and 2) number of stroke cycles completed in a 200m, free-style swim with use on a recreational swimmer.

Significance. In 2014, over half of American consumers developed a strong interest in wearable fitness trackers and the demand for these devices is expected to continue to grow (Business Wire, 2017; Liang et al., 2018). As awareness and consumption of wearable technology increases in the commercial sector, a primary use of these devices is to accurately log one's daily activity and monitor overall health and fitness (Bunn, Navalta, Fountaine, & Reece, 2018). Establishing whether the Moov Now is an accurate swim metric tracking system would provide recreational and elite swimmers alike with valuable information, allowing users to more effectively track one's overall health and fitness.

CHAPTER 2

REVIEW OF LITERATURE

Wearable Technology

Wearable technology seeks to improve an end-user's quality of life by tracking and reporting human data output (e.g., heart rate, skin temperature, distance travelled) (Jaewoon, Dongho, Han-Young, & Byeong-Seok, 2016). Researchers and clinicians have relied on data recorded from wearable devices to analyze multiple areas of interest such as fitness, sleep, care of the aging and elderly, and military operations (Bunn et al., 2018; Kutilek et al., 2017; Shelgikar, Anderson, & Stephens, 2016; Zhihua, Zhaochu, & Tao, 2017).

As technology advances, high-end wearable devices have been made accessible and become of interest to recreational consumers in the form of a wearable activity tracker. An activity-tracking wearable device (also known as a fitness tracker) is purposed toward encouraging an end-user to live an active and healthy lifestyle. Such devices are known to measure, record and report various physical metrics such as step count, caloric expenditure, heart rate, and sport-specific metrics. A recreational user finds and uses such information to assess current activity levels, set and achieve activity goals, and measure exercise performance. Recent studies further suggest digital activity tracking contributes to the adherence of weight loss programs and increased weight loss success (Pourzanjani, Quisel, & Foschini, 2016; Wilson, Ramsay, & Young, 2017; Yu, Abraham, Dowd, Higuera, & Nyman, 2017).

Wearable fitness tracking technology is a high demand commodity among a large sector of today's population (Jaewoon et al., 2016). In 2016, nearly 16% of Americans owned at least one wearable fitness device (Kantar WorldPanel, 2017) and about 102.4 million wearable fitness trackers were shipped worldwide (Business Wire, 2017). This demand in wearable technology is projected to grow by approximately 16.9% annually (Business Wire, 2017). Within this competitive market, large-scale vendors such as Fitbit, Garmin, Apple, and Samsung have produced wearable fitness devices. Depending on the device, these “smart watches” may offer independent GPS units, cellular data access, touch screen accessibility, and range in price from $199.95 up to $399.00, respectively. The Moov Now, however, retails for $59.95 (MOOV, 2018). While it does not offer any of the smart watch features listed above, the Moov Now is a relatively low-cost option for monitoring advanced fitness tracking measures. Additionally, the Moov Now may be more attractive and accessible to general consumers with an interest in advancing their physical fitness.

As more of these devices are introduced in to the market, the consumer may become overwhelmed and unsure as to which wearable fitness device may best assess objective metrics in relation to a particular activity. Therefore, it is essential to evaluate the accuracy and validate the various metrics of each particular device. Prior research on Fitbit and Jawbone wearable activity trackers indicated a high accuracy in regards to step count; however, these same devices produced lower accuracy when estimating total sleep time, sleep efficiency, and daily energy expenditure (Evenson, Goto, & Furberg, 2015). Further, when analyzing step count of ten consumer wearable activity trackers (e.g., Polar Loop, Garmin Vivosmart, Fitbit Charge HR, Apple Watch Sport), the validity and reliability of step count was shown to vary based on walking speed (Fokkema, Kooiman, Krijnen, Van Der Schans, & De Groot, 2017). Such findings support the need to further validate the accuracy of the various wearable fitness devices and the metrics they claim to assess. The Moov Now is one of these devices and is the focus of the proposed study, discussed in further detail in the following section.

Moov Now

Moov™ introduced its first product to the market in 2014, an artificial intelligence product designed to coach users through a workout. Since its inception, Moov has sought to combine wearable technology with the development of creative and high-end mobile applications. Currently, Moov offers two pieces of wearable fitness technology; Moov HR and Moov Now. Moov HR offers a line of heart rate monitors including a chest strap and an innovative sweatband, giving users a method of tracking exercise intensity. The Moov Now is a motion sensor device designed to track a number of activities including running, cycling, swimming, cardio boxing, and circuit training. While the Moov HR nor the Moov Now are autonomous wearable activity trackers, both sync data recorded with Moov mobile applications, available for both iOS and Android systems (MOOV, 2018).

The Moov Now includes a small band and a 9-axis Omni 3D motion sensor (15.1g, 1.1 x 0.3 x 8.9 inches). Specifically, the Moov Now detects motion across 9 axes as opposed to the standard tri-axial accelerometry (three perpendicular axes) frequently used in research (Beanland et al., 2014; Ganzevles et al., 2017; Godfrey, Bourke, Ólaighin, van de Ven, & Nelson, 2011; Hartmann, Luzi, Murer, de Bie, & de Bruin, 2009; van Hees et al., 2011). The Moov Now uses a combination of 3 sensors, each operating with 3-axes. While the standard accelerometer measures velocity, the Moov Now also includes a 3-axis gyroscope to detect rotation and a 3-axis magnetometer to detect orientation. The Moov claims the 9-axes makes it three-times more sensitive than other sensors and increases its accuracy (MOOV, 2018). Additional features of the Moov Now that are found to be uncommon in other fitness watches include the ability to report impact score (quantitative measure of the amount of force during foot strike) and stride angle (degree of opening between thighs during walking or running) when using the *Run/Walk* setting.

In the *Lap Swim* setting, swim lap pace (time in seconds measured to complete length of pool), flip turn time (amount of time to complete a flip turn), distance per stroke (meters travelled per swim stroke cycle), and number of strokes per lap are recorded while identifying which style of stroke (freestyle, breaststroke, backstroke, butterfly) an individual is performing. The Moov Now not only records and reports these extraordinary measures, but also serves as a coaching aid. The Moov Now is able to detect when a movement and its corresponding measure strays from the suggested normative range. When detected, the Moov Now will provide numeric and audible commands to assist in correcting an individual's form in an attempt to maximize performance and minimize injury (MOOV, 2018).

Based on these high performance capabilities, the Moov Now is quickly gaining recognition as a leader in the wearable technology industry and has been awarded multiple accolades in both the sports industry and technology world. (MOOV, 2018). As the Moov Now grows in popularity and more users rely on its metrics to track and improve fitness, the validation of its features becomes imperative. To date, there is no known public release of corporate research conducted by Moov ™ on the Moov Now. Additionally, there appears to be an absence of independent research on the Moov Now. The paucity of literature specific to the Moov Now further supports the need to begin establishing accuracy and reliability of the fitness metrics offered by the Moov Now.

As previously stated, the Moov Now tracks a number of activities including running, cycling, swimming, cardio boxing, and circuit training. For the purpose of the proposed study, only particular metrics related to swimming will be explored. Measures specifically analyzed include number of strokes completed (complete stroke cycle of the arm wearing the Moov Now, beginning and returning to the forward position), and total distance (meters) swam in a lap pool. The following section will further explore the activity of swimming.

Swimming

Swimming is one of the world's most popular and most recommended aerobic activities. Its low-impact, dynamic movements make this sport accessible for most ages and fitness levels (Tanaka, 2009). Swimming boasts low injury rates compared to other comparable methods of physical activity due to its non-weight bearing nature and ability to train the body in multiple planes of movement depending on stroke type (Baxter-Jones, Maffulli, & Helms, 1993). Due to its wide array of benefits and reduced risk of injury, swimming has been identified as a positive rehabilitative method for fibromyalgia patients, the elderly, as well as those with spinal cord and athletic injuries (Fernandes, Jennings, Nery Cabral, Pirozzi Buosi, & Natour, 2016; Hsu et al., 2010; Moriello, Driscoll, Jones, Turner, & Wilcox, 2017; Prins & Cutner, 1999).

While swimming has been praised for its rehabilitative abilities in clinical populations, recreational fitness enthusiasts have adopted swimming into their routine as it also provides numerous physiological benefits. Swimming has been shown to improve body composition as well as total and low-density lipoprotein cholesterol (Cox, Burke, Beilin, & Puddey, 2010). Furthermore, it is shown to develop both aerobic and anaerobic capacities (Kalva-Filho et al., 2015). The benefits of swimming in combination with low-intensity have made swimming one of the most popular sports in the world that can be enjoyed by a wide range of age and fitness levels (Mooney et al., 2017).

Recognizing its popularity, many fitness wearable developers have added the ability to track swimming metrics in their device. Common metrics recorded and analyzed include total distance, stroke recognition, stroke count, and a measurement of swim intensity (e.g., velocity, meters per stroke)(Siirtola, Laurinen, Roning, & Kinnunen, 2011). Devices that offer swim tracking typically have the ability to analyze data from the four competitive swim strokes: freestyle (front crawl), breaststroke, backstroke, and butterfly. Of these four strokes, freestyle is the most common stroke performed by swimmers (Richardson, Jobe, & Collins, 1980).

Recent Research on Swim Wearables

Recent research attempting to validate wearable technology's report of swim metrics commonly focus on distance and stroke count. One particular study examined the accuracy of the Garmin *Swim* and Finis *Swimsense* while swimming 1500m using all four competitive swim strokes. Both the Garmin *Swim* and Finis *Swimsense*, which use a tri-axial accelerometry system, were found to produce highly accurate measures of total distance, however stroke count was consistently found to be unreliable in both devices (Mooney et al., 2017). Accuracy of the stroke count feature is essential as other metrics such as stroke cycle time and distance are often derived from stroke count (Mooney et al., 2017). Recognizing that the Moov Now also reports cycle time and stroke distance, assessment of Moov Now's stroke count is fundamental. Mooney et al. (2017) also reported that freestyle stroke was found to have the highest error in detecting stroke count; further supporting the need to assess stroke count, particularly in freestyle, while using the Moov Now.

In another comparable study, stroke count, stroke rate, and distance were found to be significantly accurate and valid when wearing a tri-axial accelerometer device (e.g., Zephyr Bioharness 3) (Ganzevles et al., 2017). Although prominent producers of consumer activity trackers such as Apple, Garmin, and Fitbit have not released specific accelerometer specifications (Apple, n.d.; Fitbit, n.d.; "Garmin, n.d."), Mooney et. al. (2017) reported both the Garmin *Swim* and Finis *Swimsense* used tri-axial accelerometry. Recognizing the Moov Now operates off a 9-axis Omni 3D motion sensor (MOOV, 2018), there is further cause to establish the accuracy of the Moov Now.

Additionally, it is important to emphasize that of the validation swim metric studies reported on activity trackers, none have been conducted on recreational swimmers (Beanland et al., 2014; Ganzevles et al., 2017; Mooney et al., 2017). Previous studies relied on elite swimmers for their increased skill and technique (Nikodelis, Kollias, & Hatzitaki, 2005) in order to establish standardized metrics for swim devices (Mooney et al., 2017). A recreational swimmer's form and technique may not be comparable to that of an elite swim athlete thereby influencing the accuracy of such wearable swim sensors (Mooney et al., 2017).

Interestingly, previous research delineating how to classify a recreational swimmer from a competitive swimmer is inconsistent. For example, Jernej, Anton, Boro, and Venceslav (2008) investigated physiological responses in a maximal intensity swim between former competitive and recreational swimmers. Authors reported recreational participants were well-skilled; yet the recreational swimmer had no prior competitive experience (Jernej et al., 2008). In another study, recreational swimmers were required to have swam 2-4 times a week for the last 3 months prior to participating, however exclusion criteria based on competitive experience was not considered (Gomes, Soares Batista, & Cruz Ferreira de Jesus, 2018). Further, Leblanc, Seifert, and Chollet (2009) compared arm-leg coordination between recreational and competitive swimmers. Yet, recreational swimmers were high school students with no particular background in swimming.

Since the Moov Now is marketed to recreational users with an initiative to increase one's fitness and swim abilities, there is a need to validate the accuracy of the Moov Now swim activity tracking metrics. Furthermore, such assessments need to be conducted on recreational users being that a large sector of the fitness tracking device market is aimed toward recreational users. Therefore, the purpose of the proposed study was to assess the accuracy of swim distance and stroke count of the Moov Now on recreational swimmers while swimming freestyle.

Research Aims and Hypotheses

Research aim #1. This study aimed to determine the accuracy of the Moov Now in recording total swim distance at 200m freestyle swim in recreational swimmers.

Hypothesized outcome #1. It was expected that the Moov Now would not significantly differ ($p = .05$) in total swim distance in a 200m freestyle swim in recreational swimmers when compared to a known constant 200m distance.

Research Aim #2. This study aimed to determine the accuracy of the Moov Now in recording total stroke count at 200m in the freestyle swim in recreational swimmers.

Hypothesized Outcome #2. It was expected that the Moov Now would be in high-agreement ($ICC > .90$) with observed counts in recording total strokes at 200m in the freestyle swim in recreational swimmers.

CHAPTER 3

METHODOLOGY

Participants

A total of 52 apparently healthy recreational swimmers, male and female, ages 18 to 59 volunteered for participation in this study. Volunteers for this study were recruited through fliers placed around the Wichita State University campus as well as word of mouth in the Wichita, Kansas area. Each volunteer completed an *Informed Consent Form* (see Appendix A) approved by the Wichita State University Institutional Review Board (IRB) prior to completing any surveys or participating in data collection.

Inclusion Criteria

Volunteers completed two intake questionnaires to determine participation. Volunteers completed the *Physical Activity Readiness Questionnaire* (PAR-Q) (see Appendix B). The PAR-Q assisted in identifying volunteers that may have physiological or functional limitations to inhibit safely engaging in physical activity (e.g., swimming). Particularly, since this study requests that a volunteer be able to swim 200 meters freestyle in an indoor pool with minimal rest at the end of each pool length. Volunteers that indicated any limitations based on the PAR-Q were excluded from participation.

Additionally, participants completed the *Swim Activity Questionnaire* (SAQ) (see Appendix B), a questionnaire that inquired about a volunteers' swimming experience. Volunteers were asked to identify their current swim routine (within the last 3 months), number of years of competitive swimming or trained recreational swim that they participated in, and how recent any competitive swimming took place. The questionnaire also included common demographics such as age and gender as well as anthropometric measures such as height and weight. Volunteers indicating they presented with 3 or more years of competitive swim experience and/or have participated in elite swim competition in the last two years prior to this study were excluded from participating. For the purpose of this study, competitive swim experience included participation in recognized and elite race competition including collegiate, elite club, Ironman triathlons, or any other sanctioned swim competition.

All 52 volunteers successfully completed the intake questionnaires and participated in the study. Twelve participants, however, were removed from the study due to either his/her inability to complete the 200m freestyle swim (*n* = 9), an undesired break in freestyle swim pattern (*n* = 2), or due to Moov Now application error (*n* = 1). Table 3.1 provides a description of the remaining 40 participants.

Table 3.1

Descriptive Sum, Means, and Standard Deviations of Participant Gender, Total and Age

Gender	*N*	Age ± SD
Male	25	26.88 ± 11.55
Female	15	23.66 ± 9.26
Total	40	25.67 ± 10.74

Of the participants included in the study, the SAQ indicated that the majority of participants (40%) scored a Swim Activity Score of 0, indicating they had not swum for physical fitness in the last three months. Participants averaged less than 1 year of competitive swim experience (*M* = .42 yrs ± *SD* = .81), with 77.5% of participants indicating they had no competitive swim experience at all. Table 3.2 details the previous swim activity of the participants (n = 40). These details are helpful in defining the characteristics of recreational swimmers used in this study.

Table 3.2

Frequency and Percentage of Participants by Swim Activity Score and Years of Competitive Experience

		Frequency	Percent (%)
Swim Activity Score	0	16	40.0
	1	11	27.5
	2	3	7.5
	3	4	10.0
	4	6	15.0
Yrs of Competitive Swim Experience	0 years	31	77.5
	Less than 1 year	1	2.5
	1-3 years	8	20.0

Procedures

The intake process (e.g., informed consent form, SAQ, PAR-Q) in addition to recording height (Charder HM200P Portstad Portable Stadiometer) and weight (ZIEIS digital weight scale) were administered in the Human Performance Lab, Rm 214 at Wichita State University. Following completion of the intake process, participants transitioned to the Wiedemann Natatorium 25-meter pool in the Heskett Center at Wichita State University. It is also important to acknowledge that the pool was supervised by on duty Heskett Center lifeguards. Additionally, at least one research administrator was continuously observing the participant and pool at all times. Wichita State University IRB ethical research and conduct procedures were followed throughout the data collection process.

Swim performance measures. To determine if the Moov Now is an accurate device in detecting and reporting total swim distance and stroke count in a 200m freestyle swim, the following objective measures were collected.

Moov Now and instrumentation. Participants were fitted with the Moov Now device (Moov HQ, San Mateo, CA) on the wrist, at approximately the distal end of the ulna and radius, with the sensor on the dorsal side of the arm. The Moov Coach & Guided Workouts application (Moov HQ, San Mateo, CA) was downloaded to one iPhone 5s device, which was used for the duration of the study. All data recorded from the Moov Now wrist sensor was synced with the Moov Coach app on the iPhone 5s device. A trained administrator entered participants' demographics into the Moov Coach app and selected the swim feature to track and record the workout. Prior to entering the water, participants were instructed of the swim distance (200m freestyle) and procedures. For example, he/she was instructed that the completion of a total of four pool lengths (down and back) was considered a successfully 200m swim. He/she was also allotted a rest at the conclusion of each pool length if needed. Additionally, in an attempt to maintain consistency he/she was encouraged to avoid breaking swim pattern and try to avoid resting unless he/she was at the pool's wall (e.g., wall at the end of each pool length). As recreational swimmers demonstrate less skill and conditioning than elite swimmers, the swim distance was considerably reduced compared to similar studies (e.g., 1200m, 1500m) (Ganzevles et al., 2017; Mooney et al., 2017).

Assessment of swim distance and stroke count. To effectively verify the accuracy of the Moov Now in determining total distance swam and metrics on the number of strokes completed, a second research administrator used a hand-held video camera (Canon VIXIA HFR300 Camcorder), and recorded participants as they completed the swim. To allow for consistent footage of the swimmer and to maintain full view of swim stroke performed, the videographer walked alongside the swimmer from end-to-end of the pool. Video recording began once the participant entered the pool but prior to initiating swim and recording was discontinued at the completion of the participant's swim. Additionally, at the conclusion of the 200-meter freestyle swim, the participant remained at the pools edge while the administrator stopped the Moov Coach Application. The participant was then invited to exit the pool. Each participate completed a total of one swim trial.

Following the completion of each participant's session the Moov Now output was manually documents and then deleted off the Moov Now application on the iPhone 5s. All data, Moov Now swim metrics and video footage, was stored in a locked file cabinet in the Heskett Center, office 106A.

Verification of swim performance metrics. To identify the accuracy of the Moov Now, video footage of each participants' swim was used to verify swim distance and total stroke count. For the purpose of inter and intra reliability, three researchers independently reviewed each participant's video footage and provided a visual record of stroke count and a verification of total distance swam. Each researcher reviewed and recorded swim video footage measures on each participant two times in a non-consecutive order. A cumulative of six reviews and tallies were completed on each participant's swim video footage. All footage reviews were conducted in a consistent and controlled environment.

Swim distance. During data collection, researchers verified that any participant to be included in the study successfully completed the 200m swim (n = 40). Any participant that swam more or less than 200m was excluded. Following data collection, review of the video footage was found to be in perfect agreement amongst the three research reviewers that all remaining 40 participants successfully completed the 200m swim. Therefore, known swim distance was further verified to be a constant 200m.

Stroke count. To determine intra-rater reliability of raters' stroke count observations, Intraclass Correlation Coefficients (ICC) estimates and 95% confidence intervals ($CI_{95\%}$) were based on a single-measurement, absolute-agreement, two-way mixed-model. All raters demonstrated excellent intra-rater reliability between the 2 counts (raters 1 = 1.00, rater 2 = .946, and rater 3 = .999). As each rater displayed excellent (>.90) intra-rater reliability (Koo & Li, 2016), the mean stroke count of each rater's count 1 and count 2 was used to analyze inter-rater reliability.

To determine inter-rater reliability of stroke count, ICC estimates and their 95% confidence interval were based on a mean-rating (k = 3), absolute-agreement, two-way mixed-model. This assessment revealed an ICC of .692. The inter-item correlation revealed that while Rater 1 & 3 demonstrated excellent inter-rater reliability with a correlation of .999, Rater 2 demonstrated poor to moderate reliability (Koo & Li, 2016) with Rater 1 and Rater 3 (ICC = .532 and .526, respectively). Therefore, Rater 2 was excluded from the determination of gold standard for observed stroke count for lack of excellent (>.90) inter-rater reliability.

Excluding rater 2, ICC estimates ($CI_{95\%}$) were based on a mean-rating (k = 2), absolute-agreement, two-way mixed-model. This assessment revealed an ICC of .999 and confirmed excellent inter-rater reliability between Rater 1 and Rater 3, thus the mean of Rater 1 and Rater 3's counts of participant's total stroke count was used to determine 'gold standard' of observed stroke count.

Statistical Analysis

The following statistical analyses using IBM Statistical Package for the Social Sciences (SPSS) for Macintosh, version 25 (Armonk, NY) (SPSS) was used to analyze the proposed research questions:

1. A one-sample *t*-test ($p = 0.05$, 95% CI) was computed to determine if there was a statistically significant difference between the known distance of 200m and the total swim distance reported by the Moov Now. Absolute (Moov Now – Known) difference and percentage [(Moov Now - Known) *100/Known] difference analyses in total swim distance was also calculated.
2. To assess agreement between the observed stroke count and stroke count reported by the Moov Now, a single-measurement, absolute-agreement, two-way mixed model was assessed to determine the intraclass correlation coefficient (ICC). The 95% confidence intervals ($CI_{95\%}$) were calculated with the ICC as well as absolute (Moov Now – Observed) difference and percentage [(Moov Now - Observed) *100/Observed] difference analyses in stroke count. ICC ratings were set at >.90: excellent, .75-.90: good, .5-.75: moderate, and < .5: poor (Koo & Li, 2016).

CHAPTER 4

RESULTS

Total Swim Distance

A one-sample *t*-test ($p = 0.05$, 95% CI) was computed to determine if there was a statistically significant difference between the known distance of 200m and the total swim distance reported by the Moov Now. Absolute (Moov Now – Known) difference and percentage [(Moov Now - Known) *100/Known] difference analyses in total swim distance was also calculated.

The one-sample *t*-test did not indicate a significant difference ($p = .442$) between the known swim distance (200m) and the Moov Now swim distance. The analysis of total swim distance based on 200m indicated the Moov Now, on average ($M = 196.87 \pm SD = 25.43$), accurately detected distance swam. Table 4.1 details the comparison and mean differences in total swim difference. Absolute difference ranged from −125m to 75m, with an average absolute difference of −3.12m. A negative difference indicates the Moov Now underestimated total swim distance, while a positive difference indicates the Moov Now overestimated distance.

Table 4.1

Comparison and Mean Differences in Total Swim Distance

Observed (Mean ± SD)	Moov Now (Mean ± SD)	*p*	Absolute, % Difference
200 ± 0	196.87 ± 25.43	.442	−3.12, −1.56%

Stroke Count

To assess agreement between the observed stroke count and stroke count reported by the Moov Now, a single-measurement, absolute-agreement, two-way mixed model was assessed to determine the intraclass correlation coefficient (ICC). The 95% confidence intervals ($CI_{95\%}$) were calculated with the ICC as well as absolute (Moov Now – Observed) difference and percentage [(Moov Now - Observed) *100/Observed] difference analyses in stroke count.

The single-measurement, absolute agreement, two-way mixed model ($CI_{95\%}$) computed an ICC of .618 when comparing observed stroke count to stroke count detected by the Moov Now. Table 4.2 details the comparison and mean differences in stroke count and further depicts the Moov Now's moderate ability to accurately detect stroke count. Absolute differences in stroke count ranged from −84 to15, with an average absolute difference of −5.05 strokes. As in total swim distance, a negative difference here indicates the Moov Now measured a stroke count lower than observed, while a positive statistic indicates the Moov Now measured a stroke count higher than observed.

Table 4.2

Comparison and Mean Differences in Stroke Count

Observed (Mean ± SD)	Moov Now (Mean ± SD)	ICC ($CI_{95\%}$)	Absolute, % Difference
104.82 ± 18.94	99.77 ± 21.32	.618	−5.05, −4.03%

Further Analysis. As it was observed that Moov Now generally underestimated stroke count, a Bland-Altman method was used to examine limits of agreement ($CI_{95\%}$) between the Moov Now's estimated stroke count and the mean of the two stroke count measures taken (Moov Now and video observation) (Burton et al., 2018) to determine if there was proportional bias. The Bland-Altman plot in Figure 4.1 displays error and distribution of proportional biases within the measure of stroke count. The solid line represents the mean difference of the two methods of measurement (Moov Now and Observed), while the dashed lines above and below represent the limits of agreement within 95% confidence intervals. Data points outside limits of agreement represent possible outliers. As a paired-samples *t*-test (*a* = .05) did not reveal a significant difference (*p* = .07between the means in stroke count as reported by the Moov Now and manual counts, no proportional bias was found. Pearson's Product Correlation reveal a statistically significant moderate correlation (*p* = .000, *r* = .636).

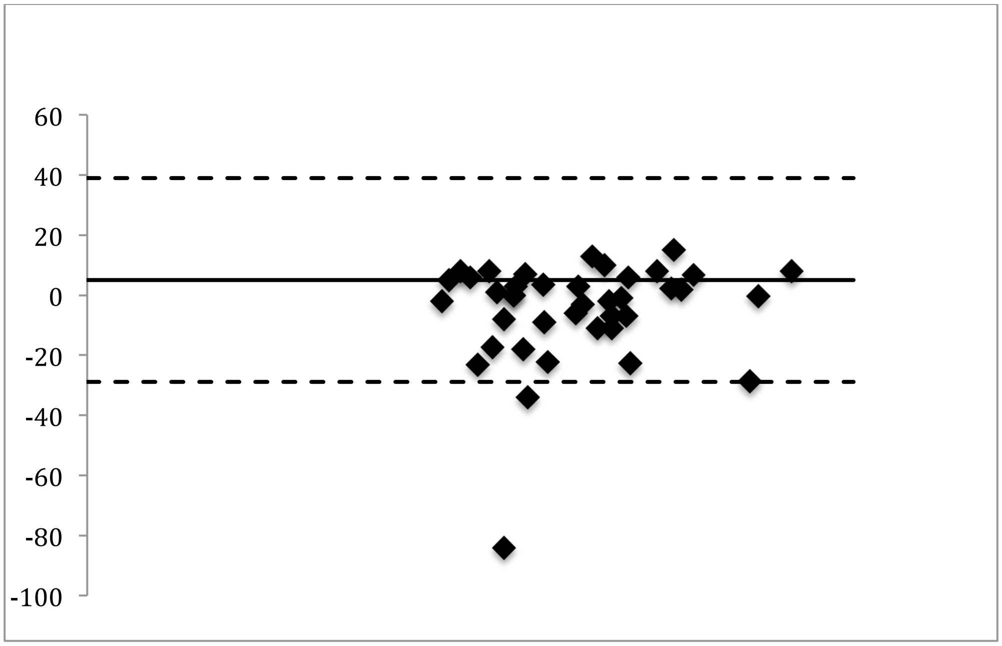

Figure 4.1 Bland-Altman Analysis of Stroke Count. Solid line is the mean difference between stroke counts counted manually from video footage, while dashed lines the 95% confidence interval. Data points below the mean difference indicate the Moov Now reported less strokes than manual counts in that trial.

CHAPTER 5

DISCUSSION

As the popularity of wearable fitness and activity trackers remains high, the validation of these devices is essential. Typically, exercise performance measures reported by devices of this nature are validated using elite athletes, due to their refined technique and consistency in biomechanics (Mooney et al., 2017; Nikodelis et al., 2005). As many consumers, however, are recreational fitness users, devices should also be analyzed for accuracy within this specific population. To date, no known validation research on wearable activity trackers has been performed on recreational populations.

The Moov Now is a recent addition to the line wearable fitness trackers with innovative features. The manufacture claims the Moov Now's 9-axis motion sensor provides real-time accuracy across a number of fitness activities (e.g., running, cycling, swimming) (MOOV, 2018). In particular, the Moov Now claims it is capable of tracking advanced swim metrics such as swim distance, identification of stroke type, stroke count, distance per stoke, stroke rate, lap time, rest time, and flip-turn time (MOOV, 2018); however, no known research has been published on the accuracy of this device. Recognizing swimming is a popular fitness activity that can be enjoyed across all stages of life and the end-user is often reliant on the output from a wearable fitness device to accurately track and analyze his/her workout. This study assessed the accuracy of the Moov Now's detection of total swim distance and total stroke count in recreational swimmers during a 200m freestyle swim.

Total Swim Distance

General findings. Results of this study support the hypothesized outcome that the Moov Now would not significantly differ in reporting total swim distance in a 200m freestyle swim in recreational swimmers when compared to the known distance, which indicates the Moov Now to be accurate in this measure. On average, the Moov Now did slightly underestimate total swim distance by 1.56%. The Moov Now reported a distance in perfect agreement with the known distance of 200m in the majority (85%) of the 40 successful trials.

Comparison to similar studies. Findings on the accuracy of swim distance by the Moov Now was consistent with findings in similar devices (e.g. Garmin *Swim*™, Finis *Swimsense*™). As in the Moov Now, neither the Garmin *Swim* nor the Finis *Swimsense* significantly differed from the known in total swim distance. While the Finis *Swimsense* reported a near perfect distance, interestingly, the Garmin *Swim* slightly underestimated distance (75m short in a 15,000m swim), with all 3 missed laps deriving from the front crawl (freestyle) portion of the swim (Mooney et al., 2017). This finding is consistent with the Moov Now's underestimation of total swim distance in the freestyle stroke. Conclusions by Wright and Stager (2013) found the Actical accelerometer-based activity monitor did not produce a significant difference (p = .051) in swim in reporting total swim distance in the freestyle swim at various distances. This further supports the present studies' findings.

Additionally, as stated previously, the Finis *Swimsense* and the Garmin *Swim* were tested on elite swimmers to minimize variation in swim stroke. Authors noted it would be reasonable to expect the devices to be less accurate in recreational swimmers (Mooney et al., 2017). The current study, however, does not fully support such a claim. The Moov Now indicated that detection of swim distance when worn by recreational swimmers was significantly accurate, despite the lack of refined technique commonly demonstrated by this population.

Total Stroke Count

General findings. In contrast to findings in total swim distance, results in the comparison of total stroke count to observed counts did not support the hypothesized outcome. The Moov Now did not report stroke count in high agreement (ICC > .90) with observed counts in recreational swimmers during a 200m freestyle swim. Analysis reported an ICC ($CI_{95\%}$) of .618, which would be classified as moderate reliability (Koo & Li, 2016). Therefore, the expected outcome was not met.

Comparison to similar studies. While the Moov Now did not report a measure of stroke count in excellent agreement with observed, its comparison to similar wearable activity trackers (e.g. Finis *Swimsense,* Garmin *Swim*), may support the Moov Now's favorability. The Finis *Swimsense* reported a stroke count that was significantly different than observed ($p < .05$) in the freestyle stroke while Garmin *Swim* did not show a significant difference in stroke count in the freestyle swim, similar to the Moov Now. Additionally, both the Finis *Swimsense* and Garmin *Swim* reported stroke count with a poor agreement (ICC = .096 and .192, respectively) when compared to observation, while the Moov Now produced moderate agreement (ICC = .618). The Finis *Swimsense* and the Garmin *Swim* also reported a higher mean absolute percentage error (14.4% & 11.4%, respectively) than the Moov Now (4.03%).

This comparison is especially surprising as the Garmin *Swim* and Finis *Swimsense* were assessed in elite swimmers, while the Moov Now was assessed in recreational swimmers. As previous research suggests recreational swimmers have less technique and coordination in swim strokes than elite swimmers (Leblanc et al., 2009; Nikodelis et al., 2005), it would be expected that the Moov Now report lower agreement in stroke count than the Finis *Swimsense* or Garmin *Swim*. A plausible reason for this interesting comparison may be the difference in the motion sensor. As previously discussed, the Garmin *Swim* and Finis *Swimsense* utilize a tri-axial accelerometer, while the Moov Now utilizes a 9-axis sensor which includes not only an accelerometer, but also a gyroscope and magnetometer. Therefore, the Moov Now may provide a more robust interpretation of the performed activity. Also, there is a notable difference in the assessment of these three devices included a variance in methodology. For example, swim length of 200m for the current study compared to 1500m in other studies. Additionally, stroke type in the current study only assessed freestyle only while the previous studies included all four strokes.

In contrast, the Zephyr Bioharness 3, a tri-axial accelerometer, was found to be accurate in detecting stroke count (Ganzevles et al., 2017). This device, however, is an accelerometer worn on the back of a swimmer, and is not a wearable activity tracker designed for quantifying recreational fitness measures, like the Moov Now. The purpose and placement of the Zephyr Bioharness 3 may account for the increase in accuracy when detecting stroke count.

Summary and Conclusion

In conclusion, findings from this study suggest that in recreational swimmers, the Moov Now may be an accurate device in measuring total freestyle swim distance. In contrast, the Moov Now may not provide excellent agreement in the detection of stroke count against observed measures, but produced higher agreement measures than similar wearable activity trackers. These findings are of importance, as consumers are purchasing and using the Moov Now to track swim metrics in their recreational fitness routines. Results suggest the Moov Now may be a suitable and affordable option for tracking recreational swimming.

Limitations of the Study

Various factors of this investigation did present with limitations. One of notability is the challenge of defining a recreational swimmer. As stated previously, similar research defines recreational swimmers in a variety of ways. The recreational swimmers in this study's population ranged from in between 0-3 years of competitive experience. The amount of recreational swim activity was recorded, but did not justify exclusion. Since recreational swimmers display less consistent proper technique than elite swimmers (Nikodelis et al., 2005), it can be reasonably assumed that the accuracy of Moov Now may vary depending on technique of swimmers.. This research did not delineate results based on participant's recreational swim activity or investigate the relationship between recreational swim activity and accuracy measures of the Moov Now.

Secondly, it is of importance to recognize the Moov Now does not rely solely on its motion sensor to report data to the user. Motion sensor information is relayed to the Moov Coach & Guided Workouts mobile application. Therefore, it is not known whether inaccuracies found in this study are at the fault of the motion sensor, mobile application, or both (Kannan & Jain, 2018). It is acknowledged that factors such as inconsistent Internet signal could have influenced accuracy measures (Case, Burwick, Volpp, & Patel, 2015).

A third and final limitation is found in the study design and procedure. Researchers did not specify which arm (right, left, dominant, non-dominant) the Moov Now would be placed on, therefore, participants were allowed to choose their preferred arm for placement of the Moov Now. Previous research suggests that arm dominance may affect coordination and velocity of arm movements in freestyle swimming (Seifert, Chehensse, Tourny-Chollet, Lemaitre, & Chollet, 2008), which could then affect device accuracy. For future studies, it is suggested that this variable is controlled for.

Further Research

Recognizing specific swim performance measures of focus (swim distance, stroke count) reported inconsistent measures of accuracy, it is of importance to consider assessing the accuracy of other Moov Now swim metrics. For example, in the recognition of swim stroke, the Moov

Now recognized freestyle swim throughout the entire 200m in 34 of the 40 (85%) trials and identified a mix of swim strokes (free, breast, back, or butterfly) in 6 of the 40 (15%) trials. It is of importance that the Moov Now not only be further assessed in the swim setting, but also in the Moov Now's other various modes such as running, biking, and boxing, as these modes also monitor and report metrics based the 9-axis motion sensor.

Additionally, the Moov Now's accuracy in detecting swim performance measures in elite swimmers is not known. As earlier discussed, as there is no known published research evaluating the accuracy of the Moov Now device, therefore it is unknown whether the Moov Now's swim metric discrepancies were derived from the chosen recreational population or the device itself. To determine this, further research of the Moov Now should be conducted to determine accuracy of the Moov Now in elite swimmers, as well as a comparison of the device's accuracy in both recreational and elite swimmers with consistent methodology.

Finally, as demonstrated by this research, it is important that accuracy of other wearable activity trackers marketed to the average consumer be assessed in recreational populations. This line of research would further educate consumers on the accuracy and reliability of various devices, which could influence purchasing decisions and application of device data outputs.

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APPENDICES

APPENDIX A

INFORMED CONSENT

WICHITA STATE UNIVERSITY

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Accuracy of Moov Now Exercise Performance Measures in Recreational Swimmers

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Purpose: You are invited to participate in a research study of the observation and assessment of exercise measures reported with a wearable fitness tracker. We hope to learn the level of accuracy of the device in regards to total swim distance and stroke count in a 200-meter freestyle swim.

Participant Selection: You were selected as a possible participant in this study because you are over the age of 18 and are able to freestyle swim 200 meters. Approximately 100 participants will be invited to join the study. Participants must be generally healthy and complete a Physical Activity Readiness Questionnaire (PAR-Q) prior to participation. If the PAR-Q indicates a participant is at a high risk for injury or harm while performing moderate cardiovascular exercise, the participant will be excluded from the study. Participants that indicate an inability to freestyle swim 200m will be excluded from this study. As this research is to be performed on recreational swimmers, participants indicating they have over 3 years of competitive swim experience or have had competitive swim experience in the previous 2 years will be excluded from this study.

Explanation of Procedures

The research will take place at the Wichita State University, Human Performance Laboratory (Rm 210), and Weidemann Natatorium Pool, Heskett Center 1845 Fairmount, Wichita, KS. If you decide to participate, you understand this is a one-time commitment lasting approximately 45 minutes. You will be first asked to sign the informed consent form approved by the Wichita State University IRB committee, allowing the research administrator(s) ability to gather information and perform the swim described below.

Data Collection

Physical Activity Readiness Questionnaire

You first will be asked to complete the Physical Activity Readiness Questionnaire (PAR-Q). This will assess your ability to participate in moderate aerobic exercise. If you answer “yes” to any of these questions, you should consult a physician before engaging in physical activity and will be excluded from participation in this study.

Swim Activity Questionnaire

The Swim Activity Questionnaire (SAQ) will obtain information about your previous swim experience. You will be asked to identify current swim routine and details about competitive swim experience. If you have a history of more than 3 years of competitive swimming or have participated in competitive swimming in the last two years, you will be excluded from this study.

You will then be asked to provide basic information such as age and gender. Your height and weight will also be measured.

If you are eligible for this study, you will be directed to the Weidemann Natatorium pool. A trained administrator will properly fit you with the Moov Now on your wrist. Your demographic information, such as age, height, and weight will be entered into the Moov Coach and Guided Workouts application on an iPhone 5s. The administrator will set the application to track your swim. To measure your swimming performance, administrators will also record your swim with a video camera positioned on a tripod. You will be asked to swim 200 meters (4 laps/8 lengths) of the pool in freestyle (front crawl) stroke. You will be allotted up to 15 seconds of rest at the conclusion of each length (25 yards) as needed. To maintain consistency, you are encouraged to not break swim pattern unless you are at the edge of the pool. At the end of your 200m swim, you will be asked to remain at the pool’s edge until you are invited by an administrator to exit the pool. Administrator’s will end the tracking of your workout through the Moov application and stop video recording at this time. Throughout the study, photographs and/or video may be used to document study procedures. De-identified media may be used for study publication purposes.

Discomfort/Risks: Possible discomforts include fatigue from aerobic exercise, muscular fatigue, and skin irritation near the ankle from Moov Now band interaction with skin. Possible risks include drowning and subsequent death. You will be monitored by at least one administrator and trained on-duty lifeguards during all swim activities.

Benefits: Participants in the study will benefit from a greater knowledge of the accuracy of a popular fitness watch and will gain a better understanding of their typical tendencies when swimming in regards to stroke mechanics, stroke count, stroke power, and time of turns. Conclusions from the study will benefit further scientific research through the level of validation of the Moov Now.

Confidentiality: Every effort will be made to keep your study-related information confidential. However, in order to make sure the study is done properly and safely there may be circumstances where this information must be released. By signing this form, you are giving the research team permission to share information about you with the following groups:

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Wichita State University Institutional Review Board;

The researchers may publish the results of the study. If they do, they will only discuss group results. Your name will not be used in any publication or presentation about the study.

There will be no personal identifiable information made available in the pictures and/or video being used. All study related information including data and media will be stored on a password protected computer. Physical document will be kept in a locked filing cabinet. All study related information will be kept for a required period of five (5) years before being destroyed.

Compensation or Treatment for Research Related Injury:

You will not receive any financial compensation for your participation in this study.

Wichita State University does not provide medical treatment or other forms of reimbursement to persons injured as a result of or in connection with participation in research activities conducted by Wichita State University or its faculty, staff, or students. If you believe that you have been injured as a result of participating in the research covered by this consent form, you can contact the Office of Research and Technology Transfer, Wichita State University, Wichita, KS 67260-0007, telephone (316) 978-3285.

Refusal/Withdrawal: Participation in this study is entirely voluntary. Your decision whether or not to participate will not affect your future relations with Wichita State University. If you agree to participate in this study, you are free to withdraw from the study at any time without penalty.

Contact: If you have any questions about this research, you can contact our investigative team at: Dr. Heidi Bell, 316-978-5150, heidi.bell@wichita.edu or Alexus Cossell, 316-978-3340, ajcossell@shockers.wichita.edu. If you have questions pertaining to your rights as a research subject, or about research-related injury, you can contact the Office of Research and Technology Transfer at Wichita State University, 1845 Fairmount Street, Wichita, KS 67260-0007, telephone (316) 978-3285.

APPENDIX A (continued)

You are under no obligation to participate in this study. Your signature below indicates that:

- You have read (or someone has read to you) the information provided above,
- You are aware that this is a research study,
- You have had the opportunity to ask questions and have had them answered to your satisfaction, and
- You have voluntarily decided to participate.

You are not giving up any legal rights by signing this form. You will be given a copy of this consent form to keep.

____

Printed Name of Subject

____ ____________________

Signature of Subject Date

____

Printed Name of Witness

____ ____________________

Witness Signature Date

APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

ID# ____________________

SIGNATURE ____________________ DATE ____________________

SIGNATURE OF PARENT ____________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

...continued from other side

PAR-Q & YOU

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

CANADA'S Physical Activity Guide
to Healthy Active Living

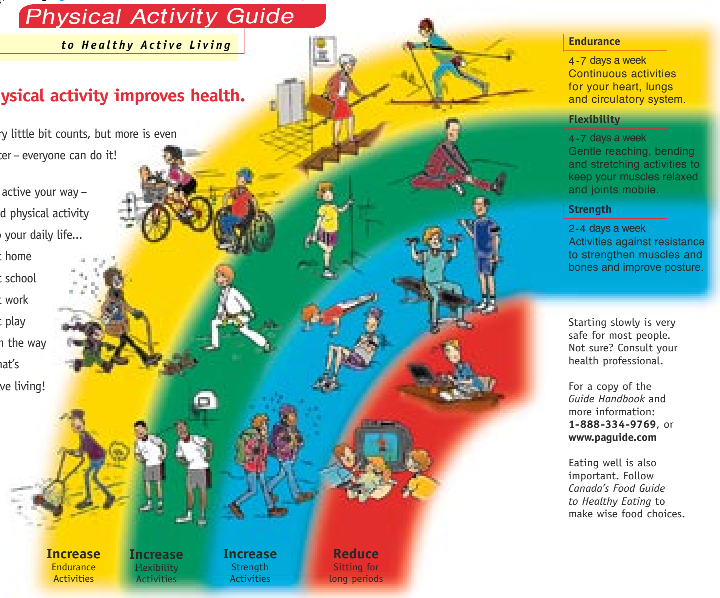
Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

- at home
- at school
- at work
- at play
- on the way

...that's active living!



Choose a variety of activities from these three groups:

Endurance
4-7 days a week
Continuous activities for your heart, lungs and circulatory system.

Flexibility
4-7 days a week
Gentle reaching, bending and stretching activities to keep your muscles relaxed and joints mobile.

Strength
2-4 days a week
Activities against resistance to strengthen muscles and bones and improve posture.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the *Guide Handbook* and more information: **1-888-334-9769**, or **www.paguide.com**

Eating well is also important. Follow *Canada's Food Guide to Healthy Eating* to make wise food choices.

Get Active Your Way, Every Day–For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly... and build up.

Time needed depends on effort

Very Light Effort	Light Effort *60 minutes*	Moderate Effort *30-60 minutes*	Vigorous Effort *20-30 minutes*	Maximum Effort
• Strolling • Dusting	• Light walking • Volleyball • Easy gardening • Stretching	• Brisk walking • Biking • Raking leaves • Swimming • Dancing • Water aerobics	• Aerobics • Jogging • Hockey • Basketball • Fast swimming • Fast dancing	• Sprinting • Racing
	Range needed to stay healthy			

You Can Do It – Getting started is easier than you think

Physical activity doesn t have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can–get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk–gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don t have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:

- better health
- improved fitness
- better posture and balance
- better self-esteem
- weight control
- stronger muscles and bones
- feeling more energetic
- relaxation and reduced stress
- continued independent living in later life

Health risks of inactivity:

- premature death
- heart disease
- obesity
- high blood pressure
- adult-onset diabetes
- osteoporosis
- stroke
- depression
- colon cancer

Health Canada Santé Canada

Canadian Society for Exercise Physiology

ACTIVE LIVING

Cat. No. H39-429/1998-1E ISBN 0-662-86627-7

CANADA'S Physical Activity Guide to Healthy Active Living

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf

FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

References:

Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. **J. Clin. Epidemiol.** 45:4 419-428.

Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy, In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health**. Champaign, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). **Can. J. Spt. Sci.** 17:4 338-345.

For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (revisé 2002)».

Supported by: Health Canada Santé Canada

APPENDIX C

SWIM ACTIVITY QUESTIONNAIRE (SAQ)

Swim Activity Questionnaire (SAQ)

Participant #:____________

1. Consider your current swimming routine in the past 3 months. How frequently do you swim for physical exercise? Check one.

	I have not swam for physical exercise in the last three months (0 pts)
	I occasionally swim (1-2 times in the past 3 months) (1pt)
	I swim about once a month (2pts)
	I swim about once a week (3pts)
	I swim more than once a week (4pts)

2. How many years of competitive swim experience do you have? Check one.

	I do not have any competitive swim experience.
	I have less than 1 year of competitive swim experience
	I have 1-3 years of competitive swim experience
	I have more than 3 years of competitive swim experience

3. If you have competitive swim experience, when did your last swim competition occur? Check one. If you have not had any competitive swim experience, check N/A.

	N/A
	My last swim competition was within 2 years of today.
	My last swim competition was over 2 years ago.

APPENDIX D

DATA COLLECTION SHEET

Accuracy of Moov Now Exercise Performance Measures in Recreational Swimmers

Data Collection Sheet

Participant #: _____________

Questionnaire Data

___ Informed Consent

___ PAR-Q

___ SAQ

_____ Swim Activity Score

_____ Years of competitive swimming

Demographics

Age: ____________

Gender: __________

Height (cm): __________

Weight (kg): ___________

Swim Data

Moov Now

Stroke Identified: _________

Swim Distance: __________

Total Stroke Count: _________

Stroke Rate: _________

Distance Per Stroke: _________

Known

Did participant complete all 8 lengths (4 laps)? Y / N

Rater 1:	*Rater 2:*	*Rater 3:*
Stroke Count 1:_______	Stroke Count 1:_______	Stroke Count 1:_______
Stroke Count 2:_______	Stroke Count 2:_______	Stroke Count 2:_______

APPENDIX E

IRB LETTER OF APPROVAL

Date: November 12, 2018

Principal Investigator: Heidi Bell

Co-Investigator(s): Alexus Cossell, Edward Pfluger, Megan Heppner

Department: HPS

IRB Number: 4280

Review Category: 4 and 6

The Wichita State University Institutional Review Board (IRB) has reviewed your research project application entitled, **"Accuracy of Moov Now Exercise Performance Measures in Recreational Swimmers".** The IRB approves the project according to the Federal Policy for the Protection of Human Subjects. As described, the project also complies with all the requirements and policies established by the University for protection of human subjects in research.

This approval is for a period of one year from the date of this letter and will require continuation approval if the research project extends beyond **November 11, 2019**.

Please keep in mind the following:

1. Any significant change in the experimental procedure as described should be reviewed by the IRB prior to altering the project.
2. When signed consent documents are required, the principal investigator must retain the signed consent documents for at least five years past completion of the research activity.
3. At the completion of the project, the principal investigator is expected to submit a ***final report***.

Thank you for your cooperation. If you have any questions, please contact the IRB Administrator at IRB@wichita.edu.

Sincerely,

Michael Rogers, Ph.D.
Chairperson, IRB

Wichita State University, Wichita, Kansas 67260-0007 Telephone: (316) 978-3285 Fax: (316) 978-3750