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Original Research

Changes in Blood Bone Metabolism Markers with Oat Bran Consumption and Brisk Walking Exercise in Middle Age Hypercholesterolemic Women

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ABSTRACT

Purpose

To investigate the additional beneficial effects of combined oat bran consumption and brisk walking exercise compared to oat bran consumption alone on bone metabolism markers in 40 to 50-years-old hypercholesterolemic women.

Methods

Thirty-three hypercholesterolemic women participants aged 40 to 50-years-old were recruited and were assigned into three groups, with eleven participants per group (n=11): sedentary without oat bran consumption control (C), oat bran consumption alone (Ob), and combined oat bran consumption and brisk walking exercise (ObEx) groups. Participants in the ObEx group performed brisk walking exercise sessions 30 minutes per session, 3 sessions per week for 6 weeks. Participants in the Ob group and ObEx group consumed 18 g of oat bran powder, 7 days per week for 6 weeks. Participants' anthropometry and blood bone metabolism markers were measured at pre- and post-tests.

Results

There were no significant main effects of time ($p>0.05$) in serum total calcium, serum phosphorus and serum C-terminal telopeptide of type 1 collagen (1CTP) (bone resorption marker) concentrations in all the groups. However, significantly ($p<0.05$) increase in serum alkaline phosphatase (bone formation marker) concentration was observed in Ob group and ObEx group respectively.

Conclusion

The present observations did not show large difference in the beneficial effects of combined oat bran consumption and brisk walking compared to oat bran consumption alone on bone metabolism markers. Future studies with longer duration may be needed to elicit greater effects of combined oat bran consumption and brisk walking than oat bran consumption alone on bone metabolism markers in middle age hypercholesterolemic women.

Keywords

Bone metabolism; Brisk walking; Hypercholesterolemic; Oat bran consumption; Middle age women.

INTRODUCTION

One of the common silence diseases among the elderly is osteoporosis. Osteoporosis becomes a significant public health problem in recent years because of its association with fragility fractures. Exercise is highly recommended to improve bone health. Exercises such as brisk walking, running, jumping, resistance training and other weight-bearing exercises are beneficial to build bones and preserve bone mass.[1]

Besides exercise, bone health also can be affected by the nutritional status of an individual. It is believed that oat bran is one of the beneficial nutritional supplementations for enhancing bone health. It is known as a vital source of B-complex vitamins,

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fat, soluble fiber β-glucan[2] and also contains macronutrients and minerals such as protein, magnesium, zinc, and iron which are important for bone health.[3] Oat bran has total β-glucan and dietary fibre not less than 5.5 and 16.0% respectively with at least one-third of total dietary fiber is soluble fiber.[4] β-glucan in oat plays an important role in improving immunity and prevention against diseases.[5] A previous study carried out by Shin et al[6] reported that Polycan, a β-glucan from Aureobasidium exhibited favourable effect on ovariectomy-induced osteoporosis, and their finding implying that β-glucan may elicit beneficial effect on bone metabolism markers, such as serum calcium, phosphorus and osteocalcin.

Previous studies by Majima et al[7] and Tintut et al[8] examined the relationship between hypercholesterolemia and bone metabolism. Majimaet al[7] reported that lipid and lipoprotein oxidation by-products inhibit osteoblastic differentiation and function although serum bone specific alkaline phosphatase (BAP) was not reduced in patients with hypercholesterolemia. Furthermore, Tintut et al[8] also reported that hypercholesterolemia promotes osteoclastic differentiation and resorptive activity and have suggested that hypercholesterolemia may cause osteoporotic bone loss *via* increased bone resorption. Collectively these previous studies showed that hypercholesterolemia may reduce bone formation and enhance bone resorption.

To date, the effects of oat bran consumption on bone health are lacking. Additionally, information is also lacking on the additional beneficial effects of combined oat bran consumption and brisk walking exercise compared to oat bran consumption alone on bone metabolism markers. Therefore, the present study was proposed to investigate the combined effects of oat bran consumption and brisk walking exercise on bone metabolism markersin 40 to 50-years-old hypercholesterolemic women.

MATERIALS AND METHODS

Participants

Thirty-three adult women participants were involved in this study. Participants were screened in order to determine the inclusion criteria and they were asked to provide informed consent form. Inclusion criteria of participants were physically healthy volunteers who were free from any chronic diseases, hypercholesterolemia with total cholesterols ranged between 5.2 to 7.0 mmol/L, non-smokers and with age between 40 to 50-years-old. The exclusion criteria were individuals who had the habit of taking oat bran as daily consumption prior to the study period, engaged in any training programme and exercised more than once per week.This study was approved by the human research ethic committee of Universiti Sains Malaysia (JEPeM Code: USM/JEPeM/15100389).

Experimental Design

Participants grouping: Participants were randomly assigned into three groups with 11 participants per group: sedentary without oat bran consumption control group (C), oat bran consumption alone group (Ob) and combined brisk walking exercise with oat bran consumption group (ObEx). Participants in the control group (C) did not perform brisk walking exercise nor having oat bran consumption for 6 weeks. Meanwhile, participants in oat bran consumption alone group (Ob) consumed 18 g of oat bran per day without performing a brisk walking exercise for 6 weeks. Participants in combined oat bran consumption with brisk walking exercise consumed 18 g of oat bran per day for 6 weeks and performed a brisk walking exercise, 30 min per session, 3 sessions per week for 6 weeks.

Brisk walking exercise program: The participants in brisk walking exercise with oat bran consumption (ObEx) group were required to perform a brisk walking exercise with 30 minutes per sessions (from 6.00 p.m. to 6.30 p.m.), three sessions per week for six weeks. In each brisk walking exercise session, all the participants warmed up by performing static stretching activities together for five minutes and then followed by brisk walking for 30 minutes, and ended with cooling down with static stretching activities for five minutes. The estimated walking distance covered was approximately 2.5 km. The exercise intensity during brisk walking was set at 55% to 70% of the participants' age-predicted heart rate maximum (HR_{max}) (HR_{max}=220-age). Heart rate monitors (Polar watch) were worn by participants throughout the brisk walking sessions. In order to ensure that the exercise intensity was maintained within the targeted range, participants were required to record their post-exercise heart rate at the end of the brisk walking session. If the walking pace did not elicit a heart rate within a targeted exercise heart rate, the participants were requested to change their pace during the subsequent walking session. The brisk walking programme was carried out at the jogging track in the Health Campus of Universiti Sains Malaysia and under the supervision of the researcher. The attendance of the participants during each brisk walking session was recorded by the researcher in order to ensure that they have complied with the exercise programme.

Oat bran supplementation: The participants in both Ob and ObEx groups consumed oat bran supplementation with two sachets of oat bran powder (18 g of oat bran powder containing 3.6 g of β-glucan)[9] diluted with plain water per day, 7 days per week for 6 weeks. The participants were required to consume one sachet of oat bran powder before breakfast, and another one sachet of oat bran powder before lunch or dinner. On the exercise days, the participants in the ObEx group were required to consume oat bran one hour before brisk walking exercise.

Measurements of anthropometry: Anthropometric parameters such as body height and body weight were measured during pre- and post-tests. Body height was measured by using a stadiometer (Seca 220, Germany). Body weight was measured by a body composition analyser (Tanita, model TBF-410). Participants were required to be shoeless and wore minimal clothes during these measurements.

Blood sample collection and analysis: Six ml of blood samples were taken immediately before and after the six weeks of experimental period in the morning after a 10 hours overnight fast (drinking plain water was allowed). A blood sample was drawn from the antecubital vein of the participants. Blood taking sessions for participants in ObEx in post-test were carried out at 8.30 a.m. the next morning after performing a brisk walking exercise, i.e. 14 h post-exercise.

Blood samples were analysed for bone metabolism markers, which were serum total calcium, serum phosphorus, bone formation marker of serum alkaline phosphatase (ALP) and bone resorption markers of serum C-terminal telopeptide of type 1 collagen (1CTP). Serum total calcium, serum phosphorus and serum ALP analysis were performed in an accredited pathology laboratory (BP Clinical Lab, Malaysia). Serum 1CTP concentration was analysed using human 1CTP ELISA kit according to manufacturer's instructions and measured on VersaMax ELISA microplate reader (Molecular Devices, USA) in the laboratory in UniversitiSains Malaysia.

STATISTICAL ANALYSIS

Data were analysed using the statistical software in the Statistical Package for Social Science (SPSS) Version 22.0. All data are expressed as means and standard deviation (SD). Repeated measure ANOVA was performed to determine the significance of the difference between and within groups. Statistical significance was accepted at $p<0.05$.

RESULTS

Participant Physical Characteristics

A total of thirty-three participants with mean age: 45.0±4.0 years, mean body weight: 66.2±13.5 kg and mean body height: 153.74 ±5.03 cm completed the study. The mean age of the participants in C, Ob and ObEx group was 44.6±4.1, 45.3±4.7and 45.5±3.5years respectively. Table 1 tabulates the body height and body weight at pre-test and post-test of all the participants according to group. Repeated measures ANOVA showed that there were no significant interactions between time and intervention (df=2, F=3.025, $p=0.064$) on body weight, however there was significant time effect in body weight (df=1, F=7.287, $p=0.011$). There were no significant differences of mean body weight between all the three groups at pre-test ($p=0.133$). After 6 weeks of the study period, participants' body weight was significantly lower at post-test in Ob ($p=0.042$) and ObEx ($p=0.006$) groups compared to pre-test. The average attendance of the participants in the exercise group during training session was 99.1±3.0 %.

Bone Metabolism Markers

Table 2 illustrates the results of serum total calcium and serum phosphorus. Results of the statistical analysis showed that there were no significant interactions between time and intervention (df=2, F=1.916, $p=0.165$), and there was no significant time effect (df=1, F=0.091, $p=0.765$) in serum total calcium. Similarly, results showed that there were no significant interactions between time and intervention (df=2, F=0.237, $p=0.790$), and also no significant time effect in serum phosphorus (df=1, F=0.012, $p=0.915$).

It was found that there were no significant interactions between time and intervention (df=2, F=2.040, $p=0.148$), however there was significant time effect in serum ALP (df=1, F=30.427, $p=0.000$). Further analysis showed that there were no significant differences in serum ALP concentration between pre- and post-tests in C. However, serum ALP increased in post-test compared to pre-test in Ob (+10.27%) and ObEx (+12.98%) groups (Figure 1).

Table 1. *Mean Age, Body Height and Body Weight of the Participants*

Groups	Number of participants per group (n)	Body height (cm) (Mean ± SD)	Body weight (kg) (Mean±SD) Pre-test	Post-test	Percent difference compared to pre-test (%)
C	11	153.5±5.9	59.8±9.3	60.0±9.6	+0.33
Ob	11	153.7±5.4	67.7±14.0	67.0±13.8[a]	-1.03
ObEx	11	154.0±4.1	71.1±15.1	70.1±14.8[a]	-1.41

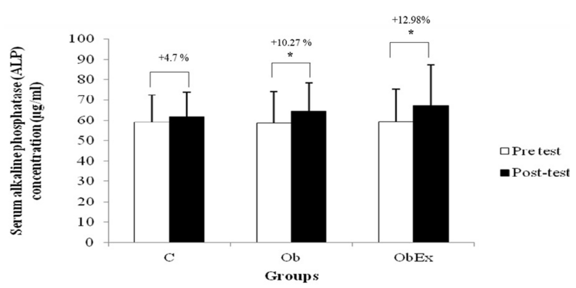
Values are tabulated in means±standard deviation (SD). [a]significantly different from pre-test (p<0.05)

Table 2. *Bone Metabolism Markers of Serum Total Calcium and Serum Phosphorus Concentration*

Groups	Serum total calcium (mmol/L)		Percent difference	Serum phosphorus (mmol/L)		Percent difference
	Pre-test	Post- test	compared to pre-test (%)	Pre-test	Post-test	compared to pre-test (%)
C	2.29 ± 0.12	2.33 ± 0.15	+1.75	1.08±0.16	1.10±0.16	+8.33
Ob	2.27 ± 0.08	2.26 ± 0.08	-0.44	1.10±0.09	1.11±0.10	+0.91
ObEx	2.28 ± 0.07	2.27 ± 0.05	-0.44	1.18±0.22	1.16±0.11	-1.69

Values are tabulated in means±standard deviation (SD).Abbreviations: C: sedentary without oat bran consumption control group;Ob: oat bran consumption alone group; ObEx: combined oat bran consumption with brisk walking exercise group.

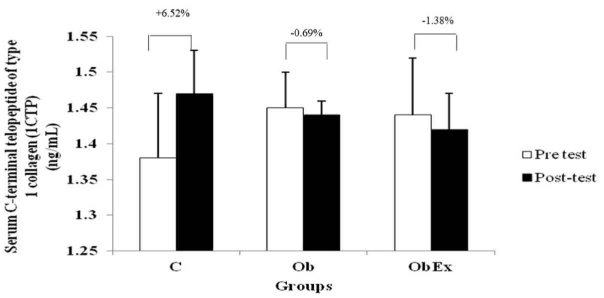
Figure 1. *Serum Alkaline Phosphatase (ALP) Concentration*



**, denotes p<0.05 significantly different from pre-test Abbreviations: C: sedentary without oat bran consumption control group;Ob: oat bran consumption alone group; ObEx: combined oat bran consumption with brisk walking exercise group.*

Regarding serum 1CTP, it was found that there were no significant interactions between time and intervention (df=2, F=0.570, p=0.572), and there was no significant time effect in this measured parameter (df=1, F=1.618, p=0.214). The results of serum 1CTP are exhibited in Figure 2.

Figure 2. *Serum C-terminal telopeptide of type I collagen (1CTP) concentration*



Abbreviations: C: sedentary without oat bran consumption control group; Ob: oat bran consumption alone group; ObEx: combined oat bran consumption with brisk walking exercise group.

DISCUSSION

Bone metabolism markers are specific biochemical markers which can estimate the bone metabolic process. These markers have been established as useful parameters in assessing changes in bone turnover.[10] In other words, bone metabolism changes can be detected indirectly *via* blood markers of bone metabolism.In this present study, serum alkaline phosphatase was measured as bone formation marker and serum C-terminal telopeptide of type 1 collagen (1CTP) was measured as a bone resorption marker. Additionally, serum total calcium and serum phosphorus were measured to reflect bone related metabolic changes.

The main finding of the present study was that there were significant increases in serum alkaline phosphatase (ALP) in oat bran alone (Ob) group and combined oat bran with exercise (ObEx) group. This finding reflects that Ob and ObEx groups could increase the level of bone formation marker and implying that both Ob alone and ObEx may elicit a beneficial effect on bone health by stimulating bone formation. Nevertheless there was no large difference in the percentage increase in serum ALP in ObEx (+12.98%) and Ob (+10.27%).

Regarding the relationship between bone formation marker and nutritional supplement, 6 weeks of daily oat bran consumption alone could increase bone formation marker, i.e. alkaline phosphatase of the present study finding has supported our hypothesis that the β-glucan, macronutrient and minerals such as protein, magnesium, zinc, and iron contained in oat bran[3] may be beneficial for enhancing bone health.[6,11-13] Similarly, a previous study also found positive effect of mineral supplemented wheat flours with magnesium, iron and zinc on increasing bone mineral density in rats.[14]

The present observation of increased alkaline phosphatase with 6 weeks oat bran consumption alone in 40 to 50-years-old women was similar with a previous study by Ooi et al,[15] which also reported an increase in alkaline phosphatase with 6 weeks honey supplementation alone in 18 to 25-years-old young females. Both the present study and study of Ooi et al[15] findings imply that 6 weeks nutritional consumption of oat bran alone or honey alone could increase bone formation marker in the female population with different age. It is speculated that both oat bran and honey contain magnesium, zinc and iron which are beneficial for enhancing bone health.[3,15,16] Therefore, the positive effects of these nutritional supplementation on bone formation marker were observed.

The present finding of combining brisk walking with oat bran did not show vast difference in percentage increase (+12.98%) in ALP than oat bran alone (+10.27%), implies that combined exercise and nutritional consumption may elicit similar beneficial effect than nutritional consumption alone. The finding of increased in serum ALP as a result of combined oat bran with walking exercise in the present study was in agreement with another combined nutritional supplementation and exercise animal study, i.e. Mosavat et al,[16] which found that serum ALP was significantly increased in 80 jumps per day combined with 5 days per week daily honey supplemented rats after 8 weeks. Similarly, a previous human study by Ooi et al[15] also reported significantly increased of serum ALP in combined honey and aerobic dance exercise group after 6 weeks experimental period compared to the pre-test value in young females.

It was mentioned in Ooi et al[17] that different exercise modes can elicit different mechanical impact on bone physically and its metabolism. Even though the type of exercise in the present study, i.e. walking was different from jumping exercise in the rats by Mosavatet al[16] and aerobic dance in young females by Ooi et al,[15] similar positive effects on bone formation were observed.

Regarding the result of bone resorption marker in the present study, it was found that there were no significant differences in serum 1CTP, a bone resorption marker after six weeks of the study period in C (+6.52%), Ob (-0.69%) and ObEx (-1.38%). In a previous study involving patients with hypercholesterolemia by Majima et al,[7] serum bone-specific alkaline phosphatase (BAP) of the patients was significantly higher than that of the controls in women. Serum N-terminal telopeptide of type I collagen (NTx), a bone resorption marker of the patients was significantly higher than that of the controls in both men and women. These results indicate increased bone turnover in hypercholesterolemic or dyslipidemic patients regardless of gender. Findings of an animal model study also demonstrated that bone mineral density (BMD) was reduced in dyslipidemic mice.[18] These findings suggest that hypercholesterolemia may be a risk factor in affecting bone metabolism or turnover markers in hypercholesterolemia subjects.

Ooi et al[19] reported that there was no significant difference in serum 1CTP with Eurycoma longifolia Jack consumption alone after 8 weeks of intervention period compared to pre-test in adult men. Similarly, a significant reduction in 1CTP was not observed in oat bran alone group in the present study. The absence of significant change in serum 1CTP was also reported by Ooi et al,[15] which showed that there was no significant difference in 1CTP between pre- and post-tests in aerobic dance exercise combined with honey consumption groups in young females. Similarly, a previous study by Rahim et al[20] also reported that after 8 weeks of the experimental period, serum 1CTP level did not change significantly in post-test compared to pre-test value in honey combined with aerobic dance in adult women. In a previous animal study done by Tavafzadehet al,[21] lower level of serum 1CTP was observed in combined jumping exercise with honey group compared to other experimental groups in young female rats. Comparison between the present study finding with the human study of Ooi et al[15] and Rahim et al[20] showed that significant changes in serum 1CTP were not observed with neither oat bran nor honey when combined with exercise in young females and adult women. Nevertheless, the comparison between the present study with Tavafzadehet al[21] showed that significant reduction in serum 1CTP could be observed in animals, however not in human with nutritional supplementation combined with exercise.

The present study found that serum total calcium and serum phosphorus were not affected by oat bran consumption alone and the combination of oat bran and brisk walking exercise. Rahim et al[20] found that there was significantly greater serum total calcium in post-test compared to pre-test in honey consumption alone group after 8 weeks of the study period in adult women. Their finding was not consistent with the present finding, in which oat bran consumption alone did not show any significant increase of serum total calcium in the Ob group. Comparison between Rahim et al[20] and the present study showed that honey drink may have greater potential in increasing serum total calcium than oat bran consumption in adult women. Regarding serum phosphorus, the absence of significant changes in serum phosphorus as a result of combined honey supplementation and jumping exercise in rats was reported by Mosavatet al.[16] Similarly, the present study also did not find significant change with combined oat bran and brisk walking exercise in women.

In the present study, brisk walking exercise was prescribed for middle age hypercholesterolemic women. It was mentioned by Krall et al[22] that walking is frequently recommended as a way to help to protect against loss of bone density. Brisk walking improved bone quality in elderly women.[23] Compared to other types of exercises, it is the most appropriate and safest activity for a wide spectrum of the population including the older population. Dynamic exercises can develop bone tissue better than static exercise.[24] This is because dynamic loading can create higher hydrostatic pressure gradients within bone tissue compared to a static load. Walking is a type of dynamic exercise. It was expected to observe a much greater beneficial effect of brisk walking combined with oat bran than oat bran alone on bone metabolism markers in this study. However, our observation did not show vast difference in the beneficial effects of the combination of brisk walking and oat bran compared to oat bran alone on bone metabolism markers. A future study with longer duration may be needed to elicit greater effects of combined brisk walking and oat bran than oat bran alone on bone metabolism markers.

Another notable finding in the present study was that both Ob and ObEx groups had significantly decreased values of body weight at post-test compared to pre-test. Oat bran is a type of high fiber diet that can be consumed to reduce body weight. Decker et al[25] mentioned that oats are uniquely nutritious food as they contain high amounts of soluble fiber. According to Turner et al,[26] high fiber intake diets may increase satiation and reduce hunger. Based on the finding of this previous study, we can speculate that participants may reduce the intake of daily diets after consumed oat bran supplementation during six weeks of experimental study. This finding suggests that oat bran consumption alone or combined brisk walking and oat bran consumption can be prescribed to reduce the body weight of the participants. ObEx group has higher percentage difference compared to pre-test in the reduction of body weight compared to the Ob group. Based on this evidence, though oat bran alone can elicit beneficial effect to reduce body weight, the combination of brisk walking and oat bran consumption may have potential in eliciting greater beneficial effects in reducing the body weight of the participants.

In general, the discrepancy of the finding of the measured parameters between the present study and previous studies may be due to differences in the type of exercise and duration of exercise prescribed, the age range of the participants and particularly the time of blood withdrawal after exercise. It is suggested that future studies with different exercise intensity, longer intervention period and repeated blood withdrawing after exercise are needed. The presence of exercise alone group is also needed to be included as one of the study group in future studies to determine the effect of exercise alone on bone metabolism.

CONCLUSION

In conclusion, the present study did not indicate large difference in the beneficial effects of combined daily consumption of oat bran and brisk walking exercise performed for 3 days per week, compared to oat bran consumption alone on bone metabolism markers. Therefore, future studies with longer duration may be warranted to elicit greater effects of combined oat bran consumption and brisk walking than oat bran consumption alone on bone metabolism markers in middle age hypercholesterolemic women.

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CONFLICTS OF INTEREST

None of the authors have any conflicts of interest.

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The Relationship between Pre-Season Testing Performance and Playing Time among NCAA Division II Men's Soccer Athletes Over a Competitive Season: A Pilot Analysis

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ABSTRACT

Aim

The purpose of this study was to investigate the relationships between pre-season testing performance and playing time within a Division II men's soccer team over a competitive season.

Methods

Data was collected from pre-season athletic performance testing data for 13 male National Collegiate Athletic Association (NCAA) Division II men's soccer players (age=20±1.5-years; height=180±6 cm; weight=75±7 kg), and was analyzed to determine if relationships existed between physical performance tests (countermovement jump height, peak anaerobic power in watts derived from jump height], change-of-direction performance (505-agility, modified T-test), linear speed (10 m and 30 m sprint intervals), and aerobic fitness (20 m multi-stage fitness test), and playing time over a collegiate season were provided by the University's coaching staff and retrospectively analyzed.

Results

A Pearson's moment correlations correlation revealed significant ($p<0.05$) moderate relationships between playing time and 10 m speed (r=-0.569) only.

Discussion

These results suggest that linear speed, in particular acceleration over short distance, could be a key characteristic that has some influence on playing time for Division II men's soccer players.

Conclusion

Pre-season testing of soccer players is commonly used to assess athletic potential. Minimal research has investigated the associations between these tests and playing time over the course of a collegiate season.

Keywords

Aerobic capacity; Power; Speed; Agility; National Collegiate Athletic Association (NCAA).

INTRODUCTION

Soccer requires a myriad of physiological abilities, such as aerobic capacity, linear speed, change of direction ability, and lower-body power.[1-5] Preceding investigations have investigated some of these physiological attributes, uncovering differences between elite and non-elite and starters and non-starters.[6-8] In short, these findings suggest that elite soccer players display higher levels of physiological capacity (e.g. maximal oxygen uptake (VO_2 max), linear speed), while starters possess significantly greater lower body ex-

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plosiveness (e.g. mean and peak velocity and jump height). Specific to collegiate soccer, understanding the underpinning physiological components for athletic competition is an important practice of collegiate strength and conditioning coaches.[9,10]

However, what is less known is if these measures correlate with on-field performance, or if they are a requisite for on-field success. As such, recent investigations in men's basketball,[9,11] women's soccer[10] and across men's and women's collegiate athletic programs[12] have begun to examine if physiological fitness relates to on-field performance. One way to determine on-field performance and success may be to investigate playing time. This is particularly important because oftentimes performance is associated with playing time.[13] As such, understanding if playing time correlates with physiological testing may provide insight into training practices in order to optimize training protocols for an upcoming season.

A recent study by Dawes et al[13] investigated relationships between pre-season strength and conditioning testing and in-season playing time in Division II male collegiate basketball players. In this study, Dawes et al[13] found significant correlations between playing time and upper (3 repetition max bench press, r=0.71, $p<0.05$) and lower (3 repetition max back squat, r=0.74, $p<0.05$) body strength. As it pertains to soccer, a recent investigation by Lockie et al[14] examined outcomes of soccer-specific tests in Division I male soccer players. Their findings indicated moderate effects between freshman and upperclass men in lower body power (vertical jump and left leg triple jump), linear speed (5, 10, and 30 meter sprint intervals) and anaerobic capacity (Yo-Yo Intermittent Recovery test) with meaningful differences exhibited in linear speed, anaerobic capacity and lower body power.[14] These findings exhibit a difference between soccer-specific assessments and experience level. However, especially at the collegiate level, there has been little analysis as to whether physiological fitness testing data relates to in-season playing time, and whether there are certain characteristics that may be more important.

Therefore, the purpose of this study was to investigate the relationships between pre-season testing performance and playing time among Division II men's soccer players. We hypothesized that significant relationships would exist between playing time and lower body power, change of direction speed, linear speed and aerobic capacity.

METHODS

Participants

Physiological performance testing data for thirteen (n=13) male (age=20±1.5-years.; height=180±6 cm; body mass=75±7 kg) National Collegiate Athletic Association (NCAA) Division II soccer players were used for this study. This data was collected by the university athletic performance staff as part of the team's normal pre-season testing routine and was retrospectively analyzed. Due to the disparate movement demands and physiological characteristics goalkeeper data was also excluded from this analysis.[7,8,14] Athletes that missed significant playing time (i.e., two or more games) and those that did not complete the pre-season testing were excluded from this analysis. Minutes played for each athlete over 16 regular-season games was retrieved from the university's athletics page.[15] This study was approved by the Institutional Review Board (IRB) at the University of Colorado-Colorado Springs in accordance with the ethical standard set by the declaration of Helsinki.

Protocol

All testing was performed on an outdoor synthetic soccer field approximately three weeks prior to the first game of the season to ensure adequate physiological fitness and minimal fatigue that may occur from the season. All testing was performed across two sessions separated by 48-hours to minimize the effect of fatigue. The first testing session consisted of anthropometric measurements (height and body mass), lower-body power (vertical countermovement jump (CMJ)), change of direction speed (505-agility; modified T-test), and linear speed (30 m sprint test, with both 10 meter and 30 meter intervals measured). The second testing session, performed at the same time of day (8:00-10:00 am), measured aerobic capacity *via* the 20 m multi-stage fitness test (20 m multi-stage fitness test (MSFT)).

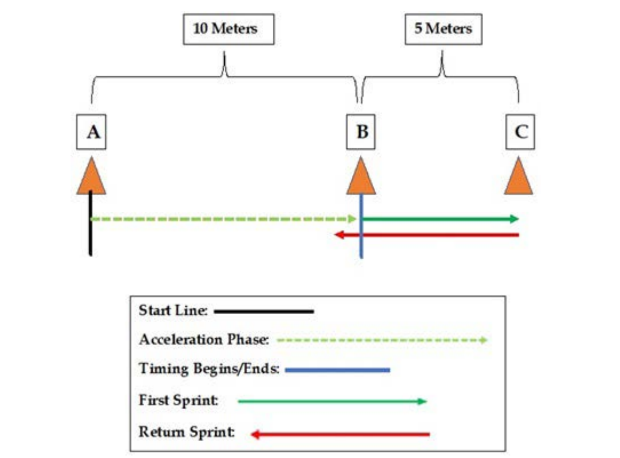
Testing Procedures

Anthropometric data: All measurements were conducted using standard procedures, with height recorded in centimeters (cm) to the nearest tenth (0.1) and body mass in kilograms (kg) to the nearest tenth (0.1) as described previously.[13,16]

Countermovement jump (CMJ): The CMJ was used as a measure of lower-body power and was performed on an electronic jump switch mat (Just Jump, Pro Botics Inc, Hunstville, AL, USA).[9,10,17,18] Participants began in a full standing position with feet placed no wider than shoulder-width and arms at the side. Participants then performed a countermovement with the arms swinging backward, occurring in a self-selected manner. Once at the bottom of this depth and without pause, participants then followed with a maximal effort jump landing in an athletic position with both feet on the mat. The best score from the three trials was recorded to the nearest 0.1 cm.[4,6,12,19] If these procedures were not adhered to, participants rested for 3-minutes and performed the jumps again. The Sayers power equation (Peak power (watts)=60.7×jump height (cm)+45.3×body mass (kg)-2055) was used to estimate total anaerobic power measured in watts (PAPw). This information was normalized for each athlete by dividing power output by total body mass to determine the power to body mass ratio (P:BM) for the CMJ.[20]

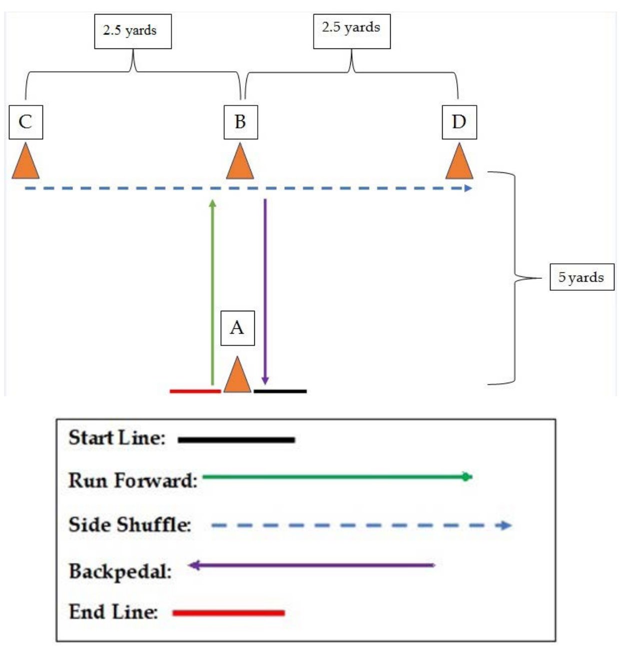
505-Agility test: The 505-agility test is displayed in (Figure 1). Participants began at cone "A" and sprinted through cone "B" to "C". An electronic timing system (TC-System, Brower Timing Systems, Draper, UT, USA) was placed at cone B and recorded the 5 m sprint from B to C, followed by a 180° turn and C and sprinting 5m back through cone B where the timing gate was placed. Two tests were performed with a left foot turn and two with a right foot turn, with the fasted time in each direction retained for analysis.[21]

Figure 1. *Modified T-test Procedure*



Modified T-test: The modified T-test (Figure 2) was used to determine change of direction (COD) speed. Participants began at cone A and sprinted to cone B. At cone B, without crossing the feet, the athlete then shuffled to cone D. Upon shuffling to cone D, the athlete then shuffled back to cone C, then returns to cone B. Once at cone B, the participant backpedaled past cone A. Time to completion was measured using an electronic timing system (TC-System, Brower Timing Systems, Draper, UT, USA). Participants performed two trials with ~3-minutes rest between each trial. Each trial was measured to the 0.1 s and the best time was used for analysis.

Figure 2. *Modified T-test Procedure*



Linear speed: Linear speed was measured by a 30 m sprint.[3] Participants began in a staggered stance with their dominant foot just behind the starting line on a weight-sensitive timing pad. Timing began upon the participant's self-volitional start, with the foot leaving the weight-sensitive footpad at the starting line. A timing gate was placed at the 10 m mark to assess acceleration, while the second timing gate was placed at the 30 m mark to assess maximum velocity (TC-System, Brower Timing Systems, Draper, UT, USA). Participants performed three trials with ~3-minutes in between each trial. Each trial was measured to the 0.1 s and the best time was used for analysis.

Aerobic endurance: Aerobic capacity was assessed using the 20 m MSFT, which is also known as the beep test. This test has been previously described by Dawes et al.[22] Specifically, two lines were marked 20 m apart. Participants began in a staggered stance with feet behind the start line. A pre-recorded auditory cue (beep) began at an initial speed of 8.5 km/h and increased by 0.5 km/h with each additional stage. This test was scored according to the final stage and shuttle the participant can achieve before being unable to run at the speed required (e.g. Stage 5.5). The test was terminated when the athlete was unable to reach the next line twice in a row in accordance with the auditory cues. Final scores by stage and shuttle were converted for the total number of shuttles completed (e.g. Stage 5.5 is 37 shuttles). The number of shuttles was then used to determine each player's estimated maximal aerobic capacity (VO_2 max).[23,24]

Statistical Analysis

A Pearson's moment correlation was performed to determine the relationships between playing time and the performance tests. The level of significance was set at $p<0.05$ for all the statistical analyses. The strength of the correlation coefficient described as per Hopkins were an 'r' value between 0 to 0.30, or 0 to -0.30, was considered low; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.50 to 0.69, or -0.50 to-0.69, large; 0.70 to 0.89, -0.70 to -0.89, very large; and 0.90 to 1, or -0.90 to -1, near-perfect or predicting relationships.[25] All analyses were performed using IBM statistical package for the social sciences (SPSS) statistics (Version 24.0; IBM Corporation, New York, USA).

RESULTS

Descriptive statistics, as well as the correlations with minutes played

Table 1. *Descriptive Statistics on DII Men's Soccer Team (n=13)*

	Minimum	Maximum	Mean±SD	Spearman's Correlation
Minutes	127	1683	904.86±536.16	-
CMJ (cm)	48.51	60.20	53.41±3.53	0.143
PAPw	3776.68	5072.99	4528.38±392.3	0.001
P:BM	54.40	66.02	60.31±2.96	0.049
10 m (sec)	1.46	1.66	1.53±0.06	-0.569*
30 m (sec)	3.87	4.33	4.03±0.13	-0.159
505 Right (sec)	2.02	2.33	2.21±0.08	-0.261
505 Left (sec)	2.21	2.40	2.31±0.06	-0.289
Mod.T (sec)	5.03	5.62	5.32±0.17	-0.448
Est.VO2	57.30	69.20	64.17±3.63	-0.094

*PAPw=Peak anaerobic power in watts; P:BM=Power-to-body mass ratio; *p<0.05* are shown in Table 1. Statistically significant, moderate relationships between playing time and 10 m (r=-0.569, p<0.05) sprint speed were discovered. No other statistically significant relationships were found between any of the remaining performance scores and playing time (Table 1).

DISCUSSION

The purpose of this study was to determine if relationships existed between pre-season testing performance and playing time in a Division II men's soccer team. The findings revealed that 10 m sprint times were significantly correlated to playing time among Division II men's soccer players (p<0.05, r=-0.569). No other significant relationships were discovered with any of the other performance variables measured. To the best of our knowledge, this is the first time these relationships have been investigated in Division II men's soccer. These findings suggest that coaches at the Division II level should aim to develop linear acceleration over short distances to enhance player performance as indicated by playing time across a competitive season.

The importance of linear speed to soccer players has been shown in other research. Prior research has exhibited findings that suggest differences in linear speed between starters and non-starters. Risso et al[8] found that in Division I female soccer players, the starters exhibited faster 10 m and 30 m sprint times. The present findings are support those of Risso et al[8] specifically that a significant relationship existed between 10 m sprint times and playing time (analogous to starter versus non-starter). Faude et al observed in professional soccer players that linear sprinting was the most frequent action observed during a 'goal scenario' which occurred as an offensive attack just prior to a goal being scored.[26] This highlights a specific match situation where linear speed is essential for soccer players.

Prior research indicates that lower body power is essential for soccer performance, specifically, that powerful actions (e.g. jumping, sprinting, kicking)[27] are required to perform movements during match play.[26] Interestingly, no significant relationships between jump height, PAPw or P:BM and playing time were observed in this study, which may be due to the level of homogeneity in jump performance within this specific group. This is in contrast to the findings of Magrini et al.[7] That study examined differences in physiological attributes between starters and non-starters of female collegiate soccer athletes, finding that starters exhibited significantly greater squat jump height when compared to non-starters.[7]

COD speed is inherent to the game of soccer, due to the multiple angles of which locomotive acceleration and decelerations occur.[2,3,10] However, in the present study, COD performance as measured by the modified T-test did not appear to significantly relate to playing time. This may be due to the homogeneity within COD performance, similar to jump performance. Previous research has indicated that COD ability is relatively similar across all freshmen and non-freshmen in Division I collegiate men's soccer team, between positions,[16] and years of experience.[28] As such, if COD performance is similar among players it would appear reasonable that COD tests may not correlate to playing time.

Additionally, no significant relationship was found between playing time and estimated max aerobic capacity as measured by the 20 m MSFT, which provided a measure of aerobic fitness. While the 20 m MSFT is not a direct marker of VO_2max, a study by Stolen et al suggests that changes in VO_2max may not actually improve on-field performance.[5] This is not to assume no relationship exists, but at the collegiate level it may not differentiate between playing time. In the present study the participants demonstrated an "above average" estimated VO_2max (i.e., 64.84+4.25 ml/kg/min) and ranked in the 90th percentile of elite soccer players.[14,29-31] These findings suggest that an average to above-average aerobic fitness may be a basic requisite at the Division II level; however, a ceiling effect may exist in which further increases in aerobic capacity may not yield better performances. This should be a focus in future research related to this topic.

This study was not without limitations. Due to the sample size, the relationships between positional differences, years of experience and academic classification (i.e. freshman-senior) were not analyzed. Previous studies have found that athletic performance, specifically the physical attributes of each athlete in soccer, may be influenced by positional differences, level of play (Division I *vs.* II *vs.* III), and sex.[10,14,16,28,32-34] This study only involved DII male's soccer players; thus, the present findings may not be generalizable to female soccer players or athletes in different divisions. Further, the focus of this study was to investigate pre-season performance testing only. It is likely that the performance variables underpinning these tests may fluctuate over the course of a season. Another consideration to understand underlying variables that attributed to playing time and soccer success should also investigate perceptual and decision-making skills to determine their impact upon playing time. While the present findings exhibit 32% of playing time explained by 10 m sprint times. Future studies should investigate additional years of data combined with playing time and injury rates in order to enhance the stability of the results found in this pilot study. This could also indicate what other factors may account for the remainder of playing time. Finally, playing time is one common denominator that can be analyzed between offensive and defensive players. It is important to understand that while playing time is not a direct measure of a player's impact, it is logical to assume better players tend to play more and is often a question of the coaching staff. Future research should explore both the quantitative and qualitative nature of player impact, correlating those measures with training load and physiological performance.

CONCLUSION

In conclusion, linear speed over 10 m was related to playing time in Division II collegiate male soccer players. These findings extend upon prior evidence suggesting speed impacts playing time and performance in female and elite soccer players.[8,26,35] For this reason, developing this attribute should be a priority within this population. Well-established techniques for improving speed and explosive strength (requisites for linear acceleration) include sprint training, Olympic lifting), and plyometrics.[9,36] Practical applications for the strength and condition practitioner that understanding of the underpinning physiological characteristics that are aimed to enhance performance on the playing field, specifically linear acceleration. Additionally, considerations for integration between the performance and sport-coaching staffs show aim to develop linear acceleration in addition to the tertiary components that facilitate resiliency to these actions that occur at a high rate of force acceleration and deceleration within soccer.

CONFLICTS OF INTEREST

None of the authors have any conflicts of interest.

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SPORTS AND EXERCISE MEDICINE

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Research Protocol

Sports Science Data Protocol

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ABSTRACT

Purpose

At the most elite level, even an increase of 1% improvement can make the difference between winning and losing. Sports scientists can help athletes gain insights that can be the differentiating factor. The purpose of this protocol is to delineate the process from the identification of key performance indicators to the presentation of the findings for sports scientists. It is designed to provide chronological steps in efforts to mitigate barriers of collecting data and tracking players as well as to help gain athlete buy-in to sports science by helping them maximize their performance.

Study Design

The competitive nature of professional sports leads to players, their agents, and teams to seek the expertise in sports performance areas such as those from athletic trainers, strength and conditioning coaches, physical therapists, nutritionists, and sports psychologists. However, much of the knowledge provided by these entities typically remain in silos. Thus, the whole picture of the athlete's performance enhancement mechanism is not elucidated. This is where the significance of a sports scientist ensues, with the ability to integrate the data from each of the sports performance areas with the objective of obtaining a complete and comprehensive picture of the athlete.

Data Collection

This area of collecting data and monitoring athletes is becoming mainstream. As such professional sports leagues have started to implement privacy rules and regulations on the protection of athlete biometric data. It is important to be aware of the rules related to wearable technology and athlete biometric data as well as how to go about the process of collecting data from professional athletes. That is why it is important that care be taken and a protocol be followed to ensure the integrity of data collection in the field of sports science.

Data Processing and Analyses

Data mining is the extraction of data for the purpose of discovering meaningful patterns, normalization, and the choosing of statistical models that can help in making data driven decisions. The interpretation and presentation of the data can have a large impact on the decisions. As such, a protocol should be adhered to.

Conclusion

The following protocol will serve as a guide on how to collect data efficiently and successfully.

Keywords

Sports science; Data protocol; Sports performance; Sports scientists; Load; Professional athletes; Sports teams.

INTRODUCTION

Professional athletes are always seeking to gain a competitive edge. A slight improvement in any aspect of sports performance can lead to a significant difference in performance outcomes.[1] It has been well-documented in the literature that different areas of sports performance such as athletic training, physical therapy, strength and conditioning, nutrition, and sports psychology function independent of one another without sharing resources and information within professional organizations.[2,3] This is where the role of the sports scientist comes in, as they can be the connecting link between these distinctive areas of expertise, as their proficiency should be to have a general understanding of all the areas and understand which outcome or dependent variables should be quantified to provide a meaningful metric that is relevant to the athlete's performance.[4] Moreover, the sports scientist should be directly in communication with the professional athletes and the sports performance experts from different areas as shown in Figure 1.

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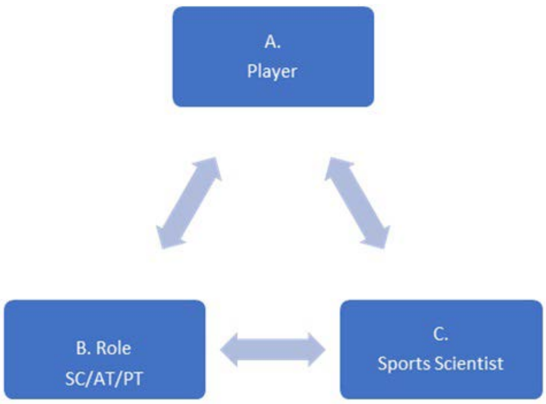
Figure 1. *Sports Scientist Role Diagram*



B. Role is a placeholder for any sports performance expert such as strength coach, athletic trainer, physical therapist, nutritionist, or sports psychologist to exemplify the direct line of communication with A. Player and C. Sports Scientist.

In many instances, due to teams being short-staffed or the lack of the role of a sports scientist, teams assign one of the aforementioned sports performance area experts to try and carry out the duties of a sports scientist.[5] Ideally, there should be a sports scientist staff with expertise to have the ability to be innovative, ask pertinent research questions, and identify key performance indicators (KPIs) or metrics that can help maximize athletic performance.[6] The role of the sports scientist comprises of knowledge on how to collect, analyze, interpret, present, and secure the data.[7] Furthermore, sports scientists in professional sports teams should have the ability to produce distinct reports to players, coaches, and front office management (general manager, assistant general manager, analytics staff).[8]

The sports scientist's first initiative should be to ask questions,[9] for instance: What are the KPIs that would help the athlete's performance? What meaningful implication will this data have? How to go about collecting data? What data is valuable and simple to measure? How to go about choosing a technology to measure the variables? How long will it take to collect this data? How to go about requesting consent from the athlete? Where is the data going to be stored? Who will have access to the data? Is the data stored in a secure location?[10]

IDENTIFICATION OF DATA-KEY PERFORMANCE INDICATORS

After answering these questions, the focus should shift to the KPIs and the type of load to be quantified. The terms load and training load (TL) are typically applied interchangeably and sub-classified as either internal load or external load. Internal load represents psychological variables such as confidence and anxiety and physiological KPIs such as heart rate variability, lactate threshold, glucose and insulin levels, etc.[11] External load is characterized by physical, biomechanical, behavioral and environmental KPIs. It is important to distinguish between internal load and external load and how they should be quantified. For instance, many of the KPIs of external loads such as power output, acceleration, and speed are derived from wearable technology such as accelerometers, gyroscopes, magnetometers, and global positioning systems (GPS). Whereas, KPIs of internal loads such as lactate threshold and rate of perceived exertion (RPE) are obtained through either biomarker assessments or self-reported questionnaires.[12]

The practical implication of measuring TL is to help the sports scientist and training staff better help the athlete by establishing appropriate TL thresholds.[13] This will also allow the sports scientist to gain insights into strengths and weaknesses of the athlete in efforts to reduce the risk of injury, examine what works for the athlete, and help them to continue to improve their performance.

Table 1. *A Measurement Model for Sports*

Physiological	Physical	Psychological	Behavioral	Environmental
Blood pressure	Agility	Anxiety	Nutrition	Built environment
Glucose and insulin	Anaerobic power	Competitiveness	Sleep	Social support groups (Coaches, Parents, Peers)
Heart rate variability	Balance	Confidence	Substance use	Socioeconomic status
Lactate threshold	Body composition	Depression		
Methylome	Cardiorespiratory endurance	Impulsiveness		
Previous injuries	Coordination ability	Intellect of sport		
Respiratory rate	Flexibility	Motivation		
Resting heart rate	Muscular endurance	Narcissism		
Telomere length	Muscular power	Perfectionism		
Vision	Muscular strength	Resiliency		
VO_2max	Reaction time	Self-efficacy		
	Sport-specific skills	Self-esteem		
		Vigor		

Source: Martin L[6]

Based on the sport, position, and player body composition some variables and KPIs may be more relevant than others. See the table below for a list of variables and KPIs related to sports performance (Table 1).

It is essential that an adequate background literature search that includes becoming knowledgeable in the sport of interest and the metrics to be quantified be performed. This process includes searching through journals, books, as well as inquiring about previous projects that may have been conducted by the team, organization, or league.[14] This will help in the development of a well-defined purpose for the KPIs that will be measured, along with the hypotheses, the purpose of collecting the data on these KPIs and how the findings will be translatable to the athlete's performance and overall team's success.[10]

CHOOSING THE WEARABLE/TECHNOLOGY AND VALIDATION

After choosing the KPIs of interest, the sports scientist should choose the appropriate measurement, assessments, and form of evaluation. Therefore, it is fundamental for sports scientists to be acquainted with and able to distinguish between measurement, assessment, and evaluation. Sports scientists should know that measurement is the assignment of numbers to quantify a characteristic being assessed, while assessment or test is a tool to make the particular measurement, and evaluation is the judgment on the quality of the assessment of the measurement.[10] Furthermore, it is a given that sports scientists know how to validate an instrument of measurement as well as establish reliability. Validity is the term used to describe whether the technology or instrument measures what it is set out to measure.[11] In the pro sports industry, there are many products of wearable technology being marketed to the training staff.[15] It is critical for the sports scientist to assess whether the technology is valid and measures what it is purported to measure or not.[16] As such, it is important to be able to evaluate how valid these technologies and instruments are by validating the technology or instrument against a gold-standard, thus establishing criterion validity. Once the instrument or technology has been chosen and validated, the focus should shift from the instrument or technology to the data output. It is ideal to obtain the raw data files as it can also help the sports scientist understand the underlying algorithm of the formulated commercialized metrics being offered by the equipment manufacturers.

ESTABLISHING INTRA-RATER AND INTER-RATER RELIABILITY TESTING

After choosing and validating a technology or instrument, it is important to conduct reliability assessments.[17] Reliability is the consistency and reproducibility of the measurement.[18] The most commonly agreed-upon types of reliability that should be assessed include absolute and relative reliability.[19] A simple way to distinguish between the two is to think about whether the assessment is cross-sectional, which would pertain to relative reliability typically assessed by intraclass correlation coefficients (ICC), or if it is a longitudinal assessment which would be indicative of absolute reliability typically assessed through the standard error of measurement (SEM). Other methods include the limit of agreement and Bland Altman plots.

It is strongly recommended that the sports scientists collecting data, establish both intra-rater and inter-rater reliability.[11] Caution is recommended when choosing reliability assessments, as there are several iterations of ICCs (Table 2) based on the number of raters or sports scientists as well as the number of athletes that will be assessed and whether absolute or relative reliability will be examined.

Table 2. *Definition of ICCs and Computation Equations*

Designation	Model	Definition	Computation Formula
ICC (1, 1)	One-way random-effect	$\sigma S^2 / \sigma S^2 + \sigma^2 e$	MSB-MSW/MSB+ (k-1)MSW
ICC (1, k)		$\sigma S^2 / \sigma S^2 + \sigma^2 e / k$	MSB-MSW/MSB
ICC (2, 1)	Two-way random-effect	$\sigma S^2 / \sigma S^2 + \sigma T^2 + \sigma^2 e$	MSB-MSE/MSB+(k-1) MSE+k(MST-MSE)/n
ICC (2, k)		$\sigma S^2 / \sigma S^2 + (\sigma T^2 + \sigma^2 e)/k$	MSB-MSE/MSB+ (MST-MSE)/n
ICC (3, 1)	Two-way mixed-effect	$\sigma S^2 / \sigma S^2 + \sigma^2 e$	MSB-MSE/MSB+ (k-1)MSE
ICC (3, k)		$\sigma S^2 / \sigma S^2 + \sigma^2 e / k$	MSB-MSE/MSB

Adapted from Li et al.[20]

The applied recommendations include practicing setting up the technology to gather data on yourself, peers and other volunteers. The purpose of this practice is three-fold, 1) to become efficient and confident in implementing the technology, 2) establish intra- and inter-rater reliability and 3) be aware of any barriers or hardware difficulties that may come up with the equipment or instrument that will be used to collect the data.

It is important to make it an easy and successful trial the first time around otherwise it may be difficult to obtain player buy-in. Therefore, it is recommended that the wearable or player tracking device be initially implemented on professional athletes that buy-in and are likely to be compliant. The reality is that with high profile athletes one needs to be cautious as there may not be a second opportunity. Therefore, it is important to be confident and efficient when approaching them. If the professional team or league has a B team, a second division, a minor league, or a G league (the NBA's official minor league), this may be an ideal starting place to see what technology the athletes gravitate towards and which end up being impractical.[21] It would be ideal to have this scenario as a pilot trial. If that is not an option or there is a strong appeal from the majors or 1st division teams, then be particular as to which technologies to present, while avoiding overwhelming the players.[22]

PRESENTATION TO THE PLAYERS

A major barrier for collecting data can be a lack of buy-in from the athletes. In order to obtain player buy-in, the following are recommended: give a general presentation to the group of players, have a one on one meeting with each player if possible, and provide the rationale for collecting the athlete's data. Remember professional athletes are inundated daily with media, autograph requests, and their own training and performance. Typically, it is rare to find a professional athlete to volunteer to be assessed, although there are a few exceptions. Many are skeptical because they don't know what is being collected, why, or how their data is going to be used.[23] Therefore, these concerns need to be addressed upfront.

To address their concerns, it is recommended that the sports scientists be familiar with the respective team's, league's, or organization's rules and regulations on player health and performance data. As each league and each organization may differ on who owns the data, how it will be used and who will have access to the data.[22] For instance, if the coaches and front office are going to have access to the data, be transparent with the athlete as they have a right to know. Ideally, it would be optimal if the team, league, or organization has granted permission to allow the player to choose whom he wants to show the data to.

Explain what will be collected and how it will relate to their performance. Emphasize that the main purpose of collecting and analyzing data is to prevent injuries and maximize sports performance. Be honest about how the data is going to be used and who will have access. This leads us to the next section.

INFORMED CONSENT FORM

Informed consent forms are basically a contract between the player and the sports scientists detailing how the data will be collected, what type of data will be collected, what is the intended use of the data, and who will have access to the data. It is a written statement granting permission to the sports scientist to obtain the player's data for the specified purposes on a voluntary basis.[23] If the team, league or organization supply a form, implement the form provided, otherwise, draft up a consent form that provides at least the following: rationale for collecting data, assessments that will be conducted along with a short description of each and how the outcomes translate to performance. Also, on the informed consent, there should be a space for the athlete's printed name, signature, date, and sports scientist's initials that is providing the informed consent. There should also be an area that describes who the athlete is willing to grant access to the data.[24] Of course, check that this informed consent is compliant with the professional league's, team's or sports organization's policy.

COLLECTION OF DATA

If all the prior steps have been completed, this part becomes simple. Set up a date and time that works well for the players and coaches.[25] Make sure that the technology or equipment that is going to be implemented has been tested and retested. Refine the processes as necessary. Try and keep everything similar, from the sports scientist's demeanor during the data collection process to the time of data collection, and situation in regard to whether the data collection will take place during practice or games.[10] Finally, keep in mind the end goal of data collection, which is to help make data-driven decisions that will increase the probability of maintaining players healthy and maximizing their performance.[22]

DATA PROCESSING AND ANALYSES

Ideally there should already be a platform in place that has an application programming interfaces (APIs) integration for the technologies that will be collecting data and servers that can hold the data securely.[26] A repository of excel built-in from the organization or a commercially available database platform or athlete management system should also be up and running. For example, currently, many of the professional leagues subscribe to an athlete management system platform that provides trends and aesthetically pleasing dashboards.[26] The next step is to make sure to have access to the raw data form and work off a copy of the original data, and aggregate to a large database. In simple terms combine the datasets from different technologies to a master dataset. This phase involves data cleaning, processing, and the handling of missing data. Running the statistical analyses will depend on the type of variables collected and the questions of interest, whether comparisons of the athlete to their prior performance or comparisons to other players will be performed.[27] Statistical modeling is a lot more complex and is not the focus of this paper, for detailed descriptions of types of analyses recommended based on variables to be collected and research questions, refer to Sports Performance Measurement and Analytics.[6]

PRESENTATION OF RESULTS

Data visualization is one of the most important aspects of this process. If the data is not presented in a simple, palatable manner then the message and content will be automatically discarded. Although it is critical to collect meaningful metrics that are relevant to the athlete's performance, it is just as important to know the audience.[28] The presentation of the data should be consistent, easy to understand and structured slightly different for each of the following; players, coaches, and front office management.[8] For example, some may prefer a more detailed report, while others may be expecting a simple chart or graph.

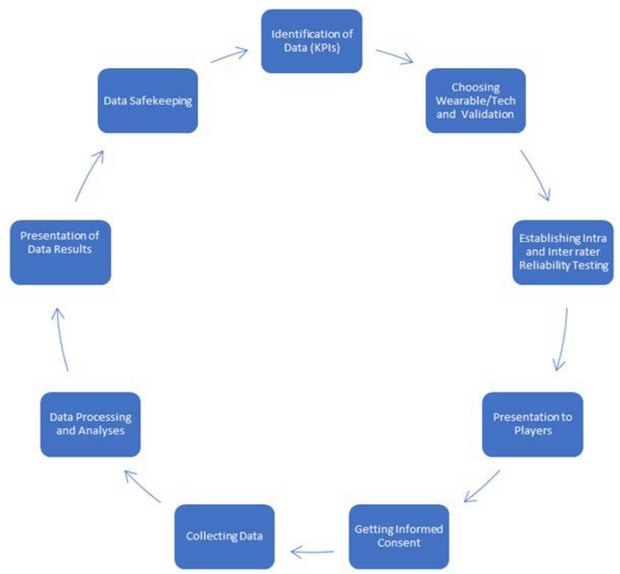
DATA SAFEKEEPING

Ensuring that the athlete's data is secure is fundamental to this protocol. Part of the security and confidentiality is included in the legislation of The Health Insurance Portability and Accountability Act of 1996 (HIPAA).[22] It requires health care providers and organizations to protect the confidentiality of protected health information (PHI), which can also include some if not all of the athlete biometric data. In addition, it covers how the data is handled, transferred and shared.[29] Furthermore, this phase typically involves being knowledgeable about the respective league, team, or organization's rules and regulations as well as collective bargaining agreements (CBAs) on player health data.[22] Depending on the league, for example, the NBA's CBA has a provision on wearable data compared to other leagues that do not. Finally, the last step is to confirm that the data is stored in a safe and secure location.[30]

CONCLUSION

The sports science data protocol is aimed at guiding the sports scientists through a logical progression of steps towards collecting data from professional athletes in a team, league, or organizational setting (Figure 2). The formulation of this protocol is based on a combination of experiences working for different professional sports organizations, input from professional athletes, training staff, coaches, and evidence-based research. The goal was to combine purposeful research with the applicability in professional sports settings. In theory, there would be larger sample sizes, athletes would grant their permission to have sports scientists collect their health and performance data, privacy would not be an issue, and the players would be completely compliant. This serves as a guide to understanding barriers to the collection of data from professional athletes as well as to be able to successfully overcome such obstacles. Overall, the end goal is to reduce the risk of injury and maximizing sports performance through the process delineated in the sports science data protocol.

Figure 2. *Sports Science Data Protocol Steps*



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