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Research Article

The Influence of Muscular Strength Exertion on Intermittent Running Endurance Capacity among Ball Game Players

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Abstract

This study aimed to examine the influence of muscular strength exertion and changes of direction upon intermittent running endurance capacity, and thereby clarify the correlation between total running distance covered and physical strength characteristics.

We subjected 15 university student handball players to 20-meter shuttles and measured their intermittent endurance capacity. We additionally measured their intermittent endurance capacity when performing the shuttles with changes of direction and while exerting muscular strength (carrying 30 kilograms for 5 meters) during the recovery period.

Adding the muscular strength exertion and changes of direction conditions to the intermittent running endurance exercise had the effect of significantly shortening total distance covered. All tests that included muscular strength exertion and changes of direction were significantly correlated with aerobic capacity. The measured values for all the tests that included the muscular strength exertion and changes of direction conditions were significantly correlated with one-repetition maximum for the high clean exercise.

The results suggested that in that in order to endure intermittent running while exerting muscular strength and performing changes of direction it is necessary to have a formidable aerobic capacity. It is also necessary to have a formidable 1RM for the high-clean exercise, an exercise which works the muscle group responsible for strength exertion and which exhibited a correlation with repeated changes of direction.

Keywords: Intermittent Running Endurance Capacity; Ball Game Players; Exerting Muscular Strength; Changes of Direction

Introduction

Many ball games are thought to require high aerobic capacity. As evidence for this, the amount of distance covered in a single game match is considerable. The amount of distance covered is approximately 4,500–8,000 meters in a handball match [1-3], 10,000–11,000 meters in a soccer match [4-5] and 4,000–7,000 meters in a rugby match[6-7]. Players must have the capacity to run such distances during match time. It is also known that ball game players require high anaerobic running power for certain phases of a match and that the intermittent exertion of such power is a key characteristic of ball players [1,2,4,7-8]. Thus, there have been many studies on intermittent exertion of anaerobic running power. According to the research, high aerobic work capacity is also needed for intermittent exertions of anaerobic running power with a short recovery time [9-14]. High aerobic work capacity is also considered a necessary component for sustained intermittent exertions of anaerobic running power during a match [15-16]. Studies on intermittent exertion capacity, such as one by Sakai et al [14], state that ball game matches involve many changes in running direction [17-18] and that research should evaluate changes in running direction as this would better reflect the characteristics of ball games.

In addition to running, ball games matches involve plenty of body contact. In a handball match, there are approximately 190 instances of body contact (if high and low intensity instances are counted together) [2]. In a rugby match, the number of front tackles alone is as much as 14 [19]. In order to withstand the shock of colliding with another player, getting knocked down, and supporting his/her body against such shocks, a player will exert the same muscular strength as would be required to push the other player back. These strength exertions may weaken a player's intermittent running endurance capacity. However, few studies have reported on the influence of physical contact-associated muscular strength exertion upon intermittent running endurance capacity. Against this backdrop, Akashi et al [20] measured the running endurance capacity of participants under a load condition wherein they received physical contact requiring the exertion of muscular strength to withstand it. However, the body contact in this case was passive body contact. As such, the study did not discuss muscular strength exertion that is based on dynamic physical contact.

The yo-yo test developed by Bangsbo et al [21] is used to evaluate intermittent endurance capacity for ball games. The form of movement used in the yo-yo test is a 20-meter shuttle (back and forth). However, given that ball games involve direction changes of various angles, using acute-angled direction changes would better reflect the movement form of ball games. Moreover, running capacity when sprinting at full power in a straight line is characteristically different from that when performing exerted-running, in which the runner makes swift changes of direction (COD) [22], and this difference creates a corresponding discrepancy in intermittent running endurance capacity.

Therefore, in this study, we measured intermittent running endurance capacity when running conventional straight-line 20-meter shuttles only. We also measured intermittent running endurance capacity during 20-meter shuttles with added COD to simulate the COD that occurs in ball games. In addition to these measurements, we added a dynamic muscular strength exertion condition. Our aim was to examine the influence of muscular strength exertion and exerted-running capacity on intermittent endurance capacity, and the correlation between the degree of decline in such capacity and physical strength characteristics.

Method

A. Participants

The participants in this study were 15 male handball players (mean age = 19.7±0.9; mean height = 174.6±5.6cm). We provided the participants a full explanation of the study's aims and methods of measurement, and obtained their informed consent. The study was approved by the ethics committee of Fukuoka University.

B. Physical Strength and Measurement method

1. Body Weight

Using a digital weight scale, we measured body weight of the participants once they had stripped down to their underwear.

2. Aerobic Capacity

As an index of aerobic capacity, we used the Cooper 12 minute run [23], in which participants ran as far as they could in 12 minutes. Specifically, we measured the maximum distance covered in 12 minutes on a 400-meter running track.

3. Anaerobic Capacity

As an index of anaerobic capacity, we calculated running speed over 50 meters of distance. The participants had a standing start and they used starting blocks. We measured running speed using a speed trap developed by Fitness Apollo Japan Co., Ltd.

4. COD Capacity and COD Skill

As an index of COD capacity, we measured the running speed of the COD running test [24], wherein participants ran 25 meters in an acute-angled figure-eight pattern. As an index of COD skill, we doubled the time taken to run the 25-meter pattern and subtracted this value from the time taken to run the 50-meter pattern.

5. Strength Exertion

As an index of muscular strength exertion, we measured the one-repetition maximum (1RM) for the three weight training exercises described below. We did not establish any repetitive speed conditions for any of the weight training exercises. We converted the measured results for each of the three weight training exercises into T-scores and calculated the mean T-score to obtain the strength index. We selected the three weight training exercises below because they involve the main muscles that are worked when moving with a training bag, namely the erector spinae, latissimus dorsi, biceps brachii, gluteus maximus, biceps femoris, rectus femoris, and vastus medialis [25].

I) Bench Press

We measured the participants' 1RM on the bench press exercise, wherein participants start with their arms extended, bend their arms gently so that the barbell comes to their chest, and then lift the weight until their arms are fully extended again. The bench press works the triceps, triceps brachii, serratus anterior, and pectoralis major muscles [26-28].

II) High Clean

We measured the participants' 1RM on the high clean exercise, wherein they start with a barbell hanging down and then lift it close to their collarbone and hold it there. The high clean works the gluteus maximus, semimembranosus, semitendinosus, biceps femoris, vastus lateralis, vastus intermedius, vastus medialis, rectus femoris, soleus, gastrocnemius, triceps, and trapezius [27,29].

III) Two-Hand Curl

We measured the participants' 1RM on the two-hand curl exercise, wherein they extend their arms, curl their hands around a weight, hold it, and then lift their arms to their collarbone. The two-hand curl works the brachialis, latissimus dorsi muscle, and brachioradialis [27,29].

6. Leg Extension Power

We measured leg extension power using the "Aneropress 3500" developed by Combi Corporation. Participants sat in a chair position, in which their knee joints were angled at 90°, and both feet were set into a footplate. They then conducted five leg extension movements with 15-second intervals between movements. We used the maximum value from among the five extensions as the leg extension power index.

C. Method for Measuring Intermittent Running Endurance Capacity and Intermittent Running Endurance Capacity with Strength Exertion

1. TEST I

To evaluate intermittent running endurance capacity, we used Bangsbo (1994)'s yo-yo intermittent endurance test level-2 (TEST I; see Figure 1). We set down markers: at the starting point, at 20 meters from the starting point, and at 2.5 meters behind the starting point. Participants were required to run from the starting point to the 20-meter point and then back to the starting point in time keeping up with the pacemaker beep. Once the participants made it back to the starting point, they had 5 seconds to jog around the rear marker and return to the starting point. As the participants repeated this process, the pace of the beeps was gradually increased, and participants were said to have reached a state of exhaustion when they could no longer complete a back and forth shuttle in the allotted time. We calculated the total distance covered based on the number of completed shuttles at the point of exhaustion.

2. TEST II

TEST II followed the same protocol as TEST I, the participants were required to transport a 30-kilogram training bag for five meters during the five-second jog period (see Figure 1). The participants were instructed to hold the training bag in both arms and not drag it. We calculated total distance covered in the same way as in TEST I. The pace of the beeps for TEST II was equal to the pace of the yo-yo intermittent endurance test level-1, which is slower than the pace of level-2.

1. **TEST III**

For every other shuttle, participants had to shuttle run and 20 meters with COD twice (see Figure 1). Total distance was calculated in the same way as above. TEST III followed a level-2 pace.

2. **TEST IV**

TEST IV followed the same protocol as TEST III, the participants were required to transport a 30-kilogram training bag five meters during the five-second jog period (see Figure 1). Total distance was calculated in the same way as above. The pace for TEST IV corresponded to level-1.

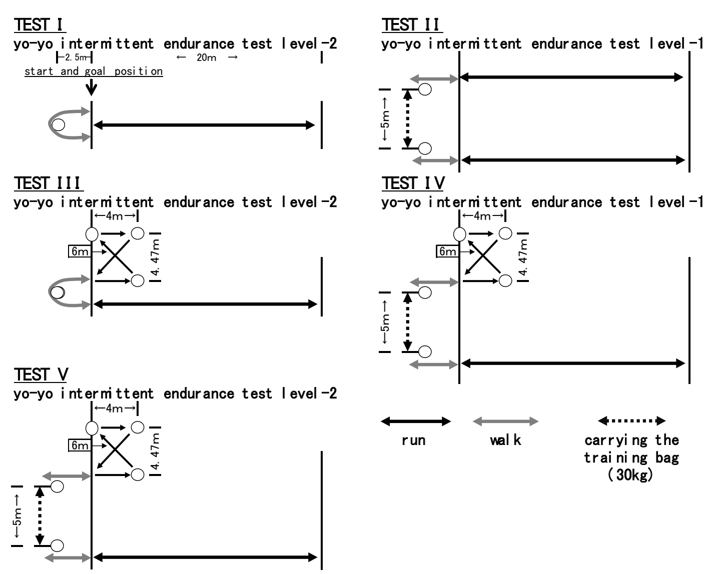


Figure 1. Design of measurement.

3. **TEST V**

TEST V followed the same protocol as TEST IV except that the pace was increased from level-1 to level-2 (see Figure 1). Total distance was calculated in the same way as above.

D. Warm-Up and Measurement Order

Participants had a 15-minute warm-up period before all of the tests. The warm-up was the same for all the participants, and it involved stretches, COD, and full sprints. Participants measured anaerobic capacity, COD capacity, muscular strength in the three weight-training exercises, and leg extension power all in the same day. Aerobic work capacity, intermittent endurance capacity, and intermittent endurance capacity with muscular strength exertion were each measured on separate days. We set an interval of one day or longer between measurements, and the order for measuring intermittent endurance capacity and intermittent endurance capacity with muscular strength exertion was randomized for each participant.

H. Statistical Processing

Measured values are reported as mean± standard deviation. We used a one-way analysis of variance and multiple comparisons (Bonferroni method) to compare the total running distances covered for each of the five tests. We used the Pearson product-moment correlation coefficient to calculate the correlation coefficients. We used an alpha rate of .05 for all statistical calculations.

Results

A. Characteristics of Participants

The participants' physical strength characteristics are shown in Table 1. The correlation coefficients between the participants' physical strength characteristics items are shown in Table 2. We observed significant positive correlations between (1) 25-meter COD running time and COD capacity; (2) high clean maximums and both 25-meter COD running time and COD capacity; and (3) strength index scores and COD capacity, leg extension power, and 1RM bench press. We found a significant negative correlation between 12-minute run times with 1RM high clean and strength index scores.

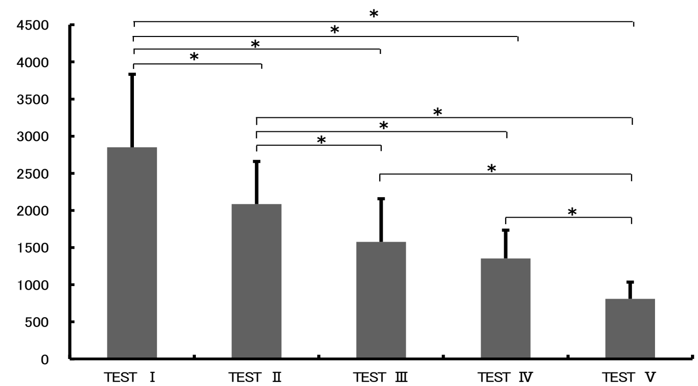
B. Total Distance Covered for Intermittent Endurance Capacity

Total distance covered (i.e., intermittent endurance capacity) is shown in Figure 2. In TEST 1, which measured only intermittent endurance capacity, total distance covered was significantly longer compared to the other tests. Total distance covered got progressively lower across test types. TEST II involved strength exertion; TEST III involved COD; TEST IV involved strength exertion and COD; and TEST V followed the protocol of TEST IV but with a higher pace.

body height	(m)	174.56 ±	5.64
body weight	(kg)	69.43 ±	5.18
50m sprint	(m/sec)	7.47 ±	0.18
COD capacity	(m/sec)	4.39 ±	0.13
COD skill	(sec)	1.70 ±	0.05
max leg extension power	(watt)	1827.13 ±	292.40
bench press	(kg)	88.00 ±	16.43
high clean	(kg)	74.50 ±	7.21
two hands curl	(kg)	35.83 ±	5.95
12minutes running	(m)	2994.33 ±	164.68

Values are mean ± S.D.

Table 1. Physical characteristics of participant.



*:P<0.05

Figure 2. Running distance in each measurement.

	TEST Ⅰ	TEST Ⅱ	TEST Ⅲ	TEST Ⅳ	TEST Ⅴ
body weight	0.150	0.119	-0.012	0.054	0.045
50m sprint	0.159	0.199	-0.058	-0.392	-0.159
COD capacity	-0.019	-0.100	-0.464	-0.437	-0.23
COD skill	0.172	0.290	0.462	0.137	0.117
max leg extension power	-0.145	0.093	0.050	-0.181	0.015
bench press	-0.446	-0.345	-0.170	-0.262	-0.376
high clean	0.404	0.649*	0.656*	0.540*	0.499
two hands curl	-0.574*	-0.424	-0.326	-0.329	-0.414
strength index	-0.278	-0.054	0.072	-0.023	-0.132
12minutes running	0.815*	0.768*	0.732*	0.735*	0.733*
TEST Ⅰ		0.827*	0.625*	0.514*	0.626*
TEST Ⅱ			0.798*	0.610*	0.829*
TEST Ⅲ				0.697*	0.728*
TEST Ⅳ					0.807*
TEST Ⅴ					

*: p< 0.05

Table 3. Correlations coefficients between physical characteristics and results measured.

C. Correlation between Total Distance Covered for Intermittent Endurance Capacity and Physical Strength Characteristics

Regarding the correlation between total distance covered for intermittent endurance capacity and physical strength characteristics, total running distances covered in TEST II, TEST III, and TEST IV were significantly positively correlated with high-clean maximums (see table 3). We also found that the distance covered in each of the intermittent endurance capacity tests were significantly positively correlated with aerobic capacity. Furthermore, an examination of the correlations between the measured values for each of the intermittent endurance capacity tests revealed a significant correlation between all of these measured values.

intermittent running endurance capacity, we compared the total distance covered in TEST I and TEST III, and in TEST II and TEST IV (differentiated, respectively, by the presence/absence of COD condition). Total distance covered in TEST III and TEST IV, both of which involved COD, was significantly shorter compared to that in TEST I and TEST II, both of which did not involve COD (see Figure 2).

	body weight	50m sprint	COD capacity	COD skill	max leg extension power	bench press	high clean	two hands curl	strength index	12minutes running
body weight		-0.029	0.336	0.400	0.211	0.343	0.444	0.228	0.458	0.026
50m sprint			0.506	0.321	0.262	0.091	0.105	0.266	0.209	-0.166
COD capacity				-0.653*	-0.003	-0.313	-0.574*	0.021	-0.391	-0.122
COD skill					0.235	0.425	0.717*	0.207	0.609*	-0.008
max leg extension power						0.638*	0.038	0.589*	0.571*	-0.288
bench press							0.104	0.890	0.900*	-0.575*
high clean								-0.041	0.480	0.407
two hands curl									0.835*	-0.608*
strength index										-0.350
12minutes running										

*: p< 0.05

Table 2. Relationship of physical characteristics.

Discussion

A characteristic of ball games is that they involve intermittent exertions. Accordingly, ball-game players need high aerobic capacity in order to exert anaerobic capacity intermittently over a long period. However, repeated strength exertions caused by body contact (a frequent occurrence in ball games) and changes of direction will have an influence on intermittent endurance capacity. Therefore, whereas past studies measured intermittent running endurance capacity only, we included COD running and strength exertion conditions in order to examine the influence of strength exertion and exerted-running capacity upon intermittent endurance capacity; moreover, we examined correlation between the degree of decline in such capacity and physical strength characteristics.

First, in order to examine the influence of strength exertion on intermittent running endurance capacity, we compared the total distance covered in TEST I and TEST II, in TEST III and TEST IV (differentiated, respectively, by the presence/absence of a strength exertion condition), and TEST V. Total distance covered in TEST II was significantly shorter than in TEST I despite the former test's pace being more slowly. Total distance covered in TEST V was significantly shorter than in TEST III, and it was also significantly shorter compared to TEST IV despite TEST IV having a more slowly pace (p < 0.059; see Figure 2). These results suggest that strength exertion during the recovery period affected intermittent running endurance capacity. This phenomenon is probably attributable to the increase in exercise caused by repeated strength exertions.

Furthermore, to examine the influence of COD running on

Hence, intermittent running endurance capacity was evidently affected by repeated instances of exerted-running power caused by COD. COD running is correlated with the muscles of the lower limbs and with power exertion [30-32]. It can therefore be surmised that repeated changes of direction weakened this muscle group and required power exertion, resulting in a shorter total distance covered.

Second, we examined the correlation between intermittent running endurance capacity with strength exertion and/or COD running, and physical strength characteristics. All of the tests were significantly positively correlated with distance covered in a 12-minute run, which is the index of aerobic capacity (see table 3). According to much research on intermittent exercise, during recovery, the aerobic energy provision mechanism replenishes the energy spent during work. The higher one's aerobic capacity the higher one's replenishment rate will be [9-14]. The yo-yo test used in our study has a five-second recovery period. Aerobic capacity helps stave off for as long as possible the point at which energy provision becomes inadequate while running speeds gradually increases the load. Accordingly, in TEST II, III, IV, and V, which involved strength exertion and/or COD, aerobic capacity would have contributed greatly to energy provision during recovery time. Therefore, the results of this study imply that aerobic work capacity is an important factor in enduring intermittent running under strength exertion and/or COD conditions.

Regarding the relationship with other physical strength characteristics, we found a significant positive correlation between the total distance covered in TEST II and TEST IV, both of which involved muscular strength exertion, and high-clean 1RM (see table 3). The high-clean exercise works the gluteus maximus, semimembranosus, semitendinosus, biceps femoris, vastus lateralis, vastus intermedius, vastus medialis, rectus femoris, soleus, gastrocnemius, triceps, and trapezius [27, 29]. The exercise also involves the main muscles that are worked when moving a training bag, namely the erector spinae muscle, latissimus dorsi muscle, biceps brachii, gluteus maximus, biceps femoris, rectus femoris, vastus medialis [25]. Given that the high-clean exercise works largely the same muscles that are worked when moving a training bag, those with a high 1RM for the high-clean exercise are able to exert muscular strength without much fatigue, which would explain why they could endure intermittent running while repeatedly exerting muscular strength.

We also observed a significant positive correlation between the total distance covered in TEST III and TEST IV, both of which involve acute-angled COD, and high-clean 1RM (see table 3). Preceding research on COD running has reported a significant negative correlation between running time and high-clean 1RM [33]. However, looking at the physical strength characteristics of the participants in the present study, there was a significant negative correlation between COD running speed and high-clean 1RM; a finding that contradicts the preceding study (see table 2). While the present study did not find a correlation between anaerobic exercise (e.g., COD running) and high-clean 1RM, the number of CODs in TEST III and TEST IV increased in proportion to total distance covered, suggesting that a correlation with high-clean was gradually emerging. Conversely, high-clean 1RM did not correlate with TEST 1, which involved only a small number of CODs. In addition, we could not find a significant correlation between high-clean 1RM and total distance covered in TEST V, which had a high running pace and involved strength exertion and COD running (see table 3). Since TEST V involved a high exercise amount and high exercise intensity, this finding suggests that the participants reached the point of exhaustion before the correlation with high-clean had a chance to emerge. It also provides further evidence that a formidable 1RM for high-clean is a necessary condition for continually performing intermittent COD (exerted-running capacity).

Summary

In order to examine the influence of muscular strength exertion and COD running upon intermittent endurance capacity, we conducted a study on 15 university student handball players wherein we measured their intermittent endurance capacity in conventional 20-meter shuttles and measured the same in 20-meter shuttles with muscular strength exertion and COD conditions included. We derived the following conclusions:

1. The addition of muscular strength exertion and exerted-running conditions to sprint-based intermittent endurance exercise caused a significant decline in the total distance covered.

2. Performance on all tests that included muscular strength exertion and/or COD running conditions were significantly correlated with aerobic capacity.

3. While high-clean 1RM was significantly correlated with tests that included muscular strength exertion and/or COD running conditions, it was not significantly correlated with performance on these tasks at a high pace.

The above results suggest that in order to endure intermittent running while exerting muscular strength and performing COD it is necessary to have a formidable aerobic capacity. It is also necessary to have a formidable high-clean 1RM, an exercise that works the muscle group responsible for strength exertion that exhibited a correlation with repeated changes of direction.

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