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Annual Changes in the Physical Characteristics of Japanese Division I Collegiate American Football Players

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ABSTRACT

This study aimed to examine the annual changes in various physical characteristics of Japanese Division I (D1) collegiate American footballers according to their positional groups. One hundred and twenty-one American football players from a D1 university in Japan were assessed for body mass, assessed performance in three one-repetition maximum (1RM) tests (bench press, back squat, and power clean), and three field tests (40-yard sprint, pro-agility shuttle, and broad jump) at each pre-season from 2014 to 2016. Data from 64 players (42 skill players and 22 linemen) who completed at least 50% (three out of six) of the performance measurements in consecutive years were used in this analysis. Performance data across the two positional groups (skill players and linemen) were analyzed using pairwise t-tests to determine annual changes. The skill players' body mass increased from their freshman to sophomore years ($p < 0.05$, Cohen's $d = 1.40$), but not from their sophomore to junior or junior to senior years. The skill players' 40-yard sprint time was shorter across all the annual comparisons ($p < 0.05$, $d = 1.10$-2.29). The linemen's body mass increased from their freshman to sophomore years ($p < 0.05$, $d = 1.81$), and stayed unchanged from their sophomore to junior years ($p = 0.99$, $d = 0.00$) and increased from their junior to senior years ($p = 0.02$, $d = 1.09$). There were significant improvements in 1RM tests, but were limited improvements in the pro-agility run and broad jump among most of the annual class comparisons for each positional group. These results indicate that annual improvements in the physical characteristics occur nonlinearly for Japanese D1 skill players and linemen. In addition, strength and conditioning coaches should consider making their training programs more specific and individualized as a player's training level or age increases.

Keywords: longitudinal study; physical characteristics; strength; speed; power

INTRODUCTION

American football is a collision sport that requires significant fitness, strength, power, speed, and quickness. The physical profiles of American football players differ between positional groups (17, 30) because each position has distinct performance demands within the game (39). Linemen (offensive and defensive) are typically more involved in activities such as blocking or tackling, which often occur at close range, while other positions (e.g., skill players) involve a combination of high-speed running, cutting, and blocking and tackling techniques. For players from the United States (US), many studies have shown that their physical abilities correlate with their actual and prospective competition levels, such as the National Football League (NFL) draft status (23) and high school recruit ranking (10).

However, little research has been conducted on the physical characteristics of players from outside the US. A previous study comparing the top-level US American football players to their Italian counterparts revealed that US players were bigger, faster, and more powerful (38). Moreover, there is a significant gap in terms of physical characteristics between the Japanese and US American football players at the top (41), collegiate (17), and high school levels (42), even though Japan is one of the leading nations in American football and had two career world championships in 1999 and 2003. In Japan, there are approximately 4,000 high school and 10,000 collegiate players (20). These statistics suggest that more than half of the Japanese collegiate American football players began playing the sport at the university level. In addition, many of these athletes transferred from other sports, whereas some began playing American football without any prior competitive sports experience, which makes creating a competitive environment for Japanese collegiate players challenging. To improve the international competitiveness of American football in Japan and address the current gap in physical characteristics, it is necessary to enhance the strength and conditioning (S&C) program and track progresses over time through longitudinal evaluations of the physical characteristics of Japanese Division I (D1) players. This will provide valuable information on the annual improvements in physical characteristics and help identify areas that may need further development.

Some longitudinal studies have sought to improve the talent identification and development systems within the various levels of American football. For example, the greatest gains in muscle mass, strength, power, and change of direction (COD) ability for the National Collegiate Athletic Association (NCAA) D1 players occurred between the freshman and sophomore years, and the 40-yard sprint time did not change over the four years of training (25, 35). Meanwhile, for D3 players, strength and power improved, and speed and COD abilities also improved slightly but significantly (16). In general, S&C programs can improve physical characteristics, howeverthese differences largely depend on the players' trainability. In the US, the number of American football players is more than one million in high school (27) and approximately 30,000, 20,000, and 20,000 players participating in NCAA D1, D2, and D3 programs, respectively (18). Most of these NCAA D1 players had shown their athletic potential in high school and were recruited to the university level (11).

Therefore, the purpose of this study was to examine annual changes (i.e., freshman to sophomore years, sophomore to junior years, and junior to senior years) in physical characteristics of Japanese D1 American football players according to positional groups. It was hypothesized that annual improvements in physical characteristics would occur, particularly in younger age categories due to their less training experience and more capacities for training.

METHODS

Experimental Approach to the Problem

A longitudinal (repeated measures) research design was used to examine annual changes in physical characteristics of Japanese D1 American football players. All the participants were from a D1 university in the Kansai Collegiate American Football League in Japan. Only data from players who completed at least 50% of the performance measurements in consecutive years were included to assess annual changes in their physical characteristics. There are eight teams in the Kansai Collegiate American Football D1 league. These teams play about four to six exhibition games during the spring season and seven league matches during the fall season (see Table 1). All the testing was conducted from late July to early August in 2014 to 2016. The period is the end of the summer off-season when the athletes reach their peaks both in strength and speed (19). As the Japanese school year begins in April, the first-year students had at least three months of resistance and field training by the time the study began. Although the participants' training histories were not investigated, it is likely that most of them had not previously engaged in specialized S&C programs prior to enrolling in university, based on a previous research (43). Two part-time S&C coaches worked for the team during the period. The S&C coaches were both certified by the National Strength and Conditioning Association (NSCA); one had the Certified Personal Trainer (NSCA-CPT), and the other had Certified Strength and Conditioning Specialist (CSCS) certification. The coaches prescribed periodized training programs for strength, power, speed, COD ability, and endurance (Table 1). Moreover, more than ten student trainers belonged to the team and supported the daily training session. General information on the league schedule and specific information on the yearly training programs on the team are shown in Table 1.

Subjects

A total of 121 American football players from a D1 university in the Kansai Collegiate American Football League participated in this study. The athletes were assessed for body mass and six performance tests for three years. This study did not include quarterbacks, punters, and kickers because of their position-specific skills (33) and the small sample size. Moreover, only data from players who completed ≥ 50% (three out of six) of the performance measurements in consecutive years were included. Ultimately, the data from 64 players (42 skill players and 22 linemen) were used in this analysis.
The data were collected as a condition of player monitoring in which the activities are routinely measured throughout the season by the team's coaching staff (40). Therefore, the team's coaches and players were previously informed of the study's procedures and purposes. The participants provided written informed consent to join the study, which was approved by the ethics committee of the institute (H27-060) and conducted according to the regulations set forth in the Declaration of Helsinki.

Procedures

The dates of birth and heights of the athletes were recorded in the team's database. The heights were measured to the nearest 1 cm during regular health checkups conducted in April of their freshman year. The one-repetition maximum (1RM) and field tests were completed on separate days in the same week at the university's S&C facility and artificial turf field, respectively. The athletes were allowed to choose their preferred time and order for the 1RM tests, typically between 9:00 AM and 6:00 PM, to accommodate their academic schedules. The field tests were conducted in a circuit fashion in the afternoon on specific days. Each player's body mass was routinely measured to the nearest 0.1 kg using a body composition analyzer (DC-320, Tanita Corp., Tokyo, Japan) before every training and testing session. The highest value during the week was used for the analysis.

The 1RM in the bench press, parallel back squat, and power clean were assessed using a standardized testing protocol by the NSCA (14). Before the session, participants completed a standardized general warm-up consisting of 10 minutes of dynamic stretching and core stability exercises. Then, they performed a standardized specific warm-up set of the given exercise, i.e., 5-10 repetitions at approximately 50% of estimated 1RM, followed by 1 set of 2–3 repetitions with loads at approximately 80% of estimated 1RM. The load was increased progressively (2.5 or 5 kg for bench press and power clean and 5 or 10 kg for squat) until muscular failure was reached or the form was severely compromised. Olympic standard 20 kg barbells and weight plates (Eleiko Sport, Halmstad, Sweden) were used for the 1RM tests. The 1RM was determined within five attempts with 3–5 minutes between trials for all tests. In the case of a failed 1RM trial, the participants who maintained proper exercise technique during the trial were permitted a second attempt at the same weight (8). The S&C coaches and/or student trainers strictly monitored the exercise techniques. The highest load lifted was used as the test score. No bouncing was permitted during the bench press. All the subjects squatted to a depth below where the thigh was parallel with the floor (24, 28). One of the S&C coaches or student trainers located laterally to the athlete strictly monitored the depth. The power clean was performed from the floor, and the bar should be caught at the clavicles and anterior deltoids with

Table 1. A brief overview of the annual league schedule and the team's training sessions.

Months	April to June	July	August	September to November	December to March
Season	Spring-season (4-6 games)	Summer off-season	Pre-season	Fall-season (7 games)	Winter off-season
Field Position	2-3/week (30 min)	2-3/week (60 min)	2-3/week (30 min)	2-3/week (30 min)	2-3/week (60 min)
Resistance training session	2-3/week (60 min)	4/week (60 min)	2-3/week (60 min)	2-3/week (60 min)	4/week (60 min)
	Hypertrophy	Strength	Strength / Power	Maintenance	Hypertrophy / Endurance

the knees and hips flexed to a half-squat position (12). An unsuccessful attempt occurred when the athlete caught the bar with their thighs below the parallel plane of the knees (4). A systematic review revealed that most of the previous studies showed excellent test-retest reliability (intraclass correlation coefficient [ICC] > 0.9) of 1RM tests (13).

During the field sessions, the 40-yard sprint, pro-agility shuttle, and broad jump were assessed with the players wearing their cleats. Before the session, participants completed a standardized warm-up, including 15-20 minutes of dynamic stretching, sub-maximal to maximal short sprints, and agility drills. Each player ran the 40-yard sprint twice with at least a 3-minute rest, and the time was measured using a custom-made photocell timing system (E3G-R13, OMRON, Tokyo, Japan), with the fastest time for each player recorded to the nearest 0.01 s. The gates were placed on the start line at the height of 70 cm, the 10-yard line at the height of 100 cm, and the goal line at the height of 100 cm. Each player began their sprint 0.5 yards (45.7 cm) behind the start line, in a 3- or 4-point stance with their finger(s) placed on the line (Fig. 1). Between-trial reproducibility of 40-yard sprint time was acceptable, with an $ICC_{2,1}$ of 0.88 (i.e., > 0.75), while the reproducibility of 10-yard lap time was not acceptable, with an $ICC_{2,1}$ of 0.62 (21). Therefore, the 10-yard lap time was not used in the subsequent analysis.

The pro-agility shuttle and broad jump were conducted in the same way as our previous studies (41, 42). Each player attempted the pro-agility shuttle twice (start to the right and left) with at least 3-minute rest. Two experienced timers measured the time for each trial concurrently using handheld stopwatches (CASIO, Tokyo, Japan). Then, these times were averaged, with the fastest time recorded to the nearest 0.01 s (9). Interrater reliability and between-trial reproducibility for pro-agility shuttle time were $ICCs_{2,1}$ of 0.89 and 0.77, respectively, indicating acceptable reliability (21).

For the broad jump, athletes started with their toes behind the start line. They were allowed to swing their arms and bend their knees and were told to jump as far as possible. Upon landing, athletes were allowed to fall forward and touch the ground if needed, but not backward. The distance was measured from the start line to the nearest heel. Athletes performed the broad jump test twice with at least 1-minute rest, and the highest score was recorded to the nearest 1 cm (43). Between-trial reproducibility for the broad jump distance was an $ICC_{2,1}$ of 0.91, indicating acceptable reliability (21).

Statistical Analyses

The athletes were categorized into two groups (skill players and linemen) based on their playing positions (16, 37). The skill players consisted of wide receivers, running backs, defensive backs, fullbacks, tight ends, and linebackers, and the linemen consisted of offensive and defensive linemen. Each variable in each positional group was compared for each consecutive year. All the variables are expressed as the mean ± standard deviation (SD). Paired t-tests were used to determine whether any changes occurred between the years. The Cohen's *d* was calculated as an effect size index for the mean comparisons. Cohen's *d* for repeated measures was calculated as $M_{diff} / SD_{pooled} \times \sqrt{(2(1-r))}$, where M_diff is the mean difference between pre and post values, SD_{pooled} is the pooled SD of pre and post values, and r is the correlation between pre and post values (26). A $|d| < 0.2$ was considered trivial, 0.2 to 0.49 small, 0.5 to 0.79 medium, ≥ 0.8 large (2, 22). The α level was set at $p < 0.05$. All the statistical analyses were performed using Microsoft Excel 2019 (Microsoft Corporation, WA, USA).

RESULTS

The skill players' body mass increased from their freshman to sophomore years ($p < 0.01$, $d = 1.81$, large), but not from their sophomore to junior ($p = 0.99$, $d = 0.00$, trivial) or junior to senior years ($p = 0.41$, $d = 0.21$, small) (Table 2). The players' performance in the bench press, squat, and power clean increased among all the annual class comparisons ($p < 0.01$, d = 0.86-3.79, large). The 40-yard sprint times decreased among all the annual class comparisons ($p < 0.01$, d = 1.10-2.29, large). The pro-agility shuttle times were shortened from their freshman to sophomore years ($p < 0.01$, d = 1.17, large) but did not change from their sophomore to junior ($p = 0.26$, $d = 0.34$, small) or junior to senior years ($p = 0.07$, $d = 0.78$, medium). The players' performance in the broad jump did not change among all the annual class comparisons, except for a medium improvement for the skill players between their freshman and sophomore years ($p = 0.04$, d = 0.62).

The linemen's body mass increased from their freshman to sophomore years ($p < 0.01$ $d = 1.81$, large), stayed unchanged from their sophomore to junior years ($p = 0.99$, $d = 0.00$, trivial) and increased from junior to senior years ($p = 0.02$, $d = 1.09$, large) (Table 3). The linemen's 1RM in bench press and power clean improved among all the annual class comparisons ($p < 0.05$, d = 1.01-8.73, large). However, 1RM of the squat improved from their freshman to sophomore years ($p < 0.01$, $d = 3.29$, large), but did not statistically improve from their sophomore to junior years and junior to senior years (p = 0.18 and 0.05, respectively), even though the effect sizes were large (d = 0.88 and 0.92, respectively). On the other hand, all field tests showed no changes between any annual comparisons ($p > 0.05$, d = 0.11-0.58, trivial to medium).

DISCUSSION

The present study aimed to investigate annual changes in physical characteristics of Japanese D1 American football players according to positional groups. The results showed that the skill players became stronger, more powerful, and faster as they progressed through the grade levels, while the linemen became heavier, stronger, and more powerful. This is the first study to investigate the longitudinal development and changes in the physical characteristics of American football players outside the US.

As with the longitudinal studies of the NCAA D1 American football players (19, 25, 35), our results showed that the greatest gains in body mass, strength, and power occurred between the players' freshman and sophomore years. One reason may be that the freshmen typically experience less playing time and have enough time to maximize their physical performance during their first year in the program (35). Another potential reason is that those who have less training experience are more trainable (1). Smart et al. observed that semi-professional and professional rugby union players did not improve their strength and speed during a single year (34). Till et al. showed that rugby league players from an English Super League club's academy experienced small-to-medium annual improvements in strength when they were 18 years old (36). Japanese D1 players, especially freshmen, showed less muscle strength than similar-aged collision sports athletes, such as rugby league players from an English Super League club's academy (36) and NCAA D1 American football players (19).

Furthermore, while annual physical improvements are usually assessed in terms of relative values, such assessments must be carefully considered in this study. For example, in this study, the Japanese skill players' 1RMs for the bench press improved by 22.5 kg (30.2%) between the players' freshman and sophomore years. This gain was similar in terms of the absolute value and much greater relative value than the NCAA D1 skill players' 20.3 kg (19.2%) improvement during this same timeframe (19). However, the general tendency for athletes was that the strength gains slowed with increased training level and experience (29). A previous study with elite-level rugby union players reported that their magnitude of strength improvement was negatively associated with their initial strength levels (1). Compared to a previous study of the NCAA D1 players (19), the 1RMs of the Japanese seniors in this study were similar to those of NCAA D1 freshmen. Therefore, it should be noted that an equivalent improvement in the absolute 1RM values between Japanese and US players may represent a smaller adaptation for the weaker (Japanese) players, despite greater relative 1RM gain, and that the gap between the performances of Japanese and US American football players may not narrow. S&C coaches should consider making their training programs more specific and personalized based on each player's training level and experience.

The Japanese D1 skill players and linemen became

Table 2. Physical characteristics and performance of skill players. Data are presented as mean ± SD.

Skill players	Year 1			Year 2			*n*	Change		*d*	Magnitude	*p*
Height (m)	1.72	±	5.0									
	Freshman			Sophomore								
Age (y)	19.5	±	0.7	20.5	±	0.7	15					
Body mass (kg)	72.6	±	5.9	77.2	±	7.0	15	4.6	(6.4%)	1.40	Large	< 0.01*
Bench press (kg)	74.5	±	12.6	97.0	±	8.4	11	22.5	(30.2%)	3.79	Large	< 0.01*
Squat (kg)	110.9	±	17.6	140.9	±	16.3	11	30.0	(27.0%)	3.63	Large	< 0.01*
Power clean (kg)	66.3	±	12.2	90.9	±	9.8	8	24.7	(37.3%)	2.99	Large	< 0.01*
40-yard sprint (s)	5.17	±	0.17	4.95	±	0.15	14	-0.21	(-4.1%)	2.29	Large	< 0.01*
Pro-agility run (s)	4.70	±	0.16	4.48	±	0.09	13	-0.22	(-4.7%)	1.17	Large	< 0.01*
Broad jump (m)	2.50	±	0.17	2.54	±	0.15	14	0.05	(1.9%)	0.62	Medium	0.04*
	Sophomore			Junior								
Age (y)	20.0	±	0.4	21.0	±	0.4	14					
Body mass (kg)	77.3	±	5.8	77.3	±	6.8	14	0.0	(0.0%)	0.00	Trivial	0.99
Bench press (kg)	99.0	±	11.7	106.3	±	10.9	10	7.3	(7.4%)	0.86	Large	0.01*
Squat (kg)	139.0	±	17.4	148.5	±	16.5	10	9.5	(6.8%)	1.15	Large	< 0.01*
Power clean (kg)	89.8	±	9.0	99.3	±	10.3	10	9.5	(10.6%)	1.53	Large	< 0.01*
40-yard sprint (s)	5.14	±	0.21	5.01	±	0.21	12	-0.13	(-2.5%)	1.34	Large	< 0.01*
Pro-agility run (s)	4.56	±	0.26	4.47	±	0.27	12	-0.09	(-2.1%)	0.34	Small	0.26
Broad jump (m)	2.49	±	0.17	2.52	±	0.17	11	0.03	(1.1%)	0.37	Small	0.24
	Junior			Senior								
Age (y)	21.3	±	0.7	22.3	±	0.7	16					
Body mass (kg)	78.6	±	8.3	79.2	±	7.9	16	0.6	(0.8%)	0.21	Small	0.41
Bench press (kg)	103.7	±	11.9	113.8	±	10.4	15	10.2	(9.8%)	2.10	Large	< 0.01*
Squat (kg)	153.1	±	10.3	163.7	±	14.7	13	10.6	(6.9%)	1.30	Large	< 0.01*
Power clean (kg)	95.0	±	8.7	101.3	±	6.8	13	6.3	(6.7%)	1.22	Large	< 0.01*
40-yard sprint (s)	5.07	±	0.19	4.93	±	0.15	16	-0.14	(-2.8%)	1.10	Large	< 0.01*
Pro-agility run (s)	4.41	±	0.21	4.40	±	0.17	16	-0.02	(-0.4%)	0.07	Trivial	0.78
Broad jump (m)	2.53	±	0.15	2.56	±	0.17	16	0.03	(1.1%)	0.26	Small	0.31

Note: * $p < 0.05$.

Table 3. Physical characteristics and performance of linemen. Data are presented as mean ± SD.

Linemen	Year 1			Year 2			*n*	Change		*d*	Magnitude	*p*
Height (m)	1.76	±	4.9									
	Freshman			Sophomore								
Age (y)	18.9	±	0.4	19.9	±	0.4	12					
Body mass (kg)	86.9	±	9.5	97.8	±	10.1	12	10.8	(12.5%)	1.81	Large	< 0.01*
Bench press (kg)	83.0	±	19.2	113.8	±	17.9	10	30.8	(37.0%)	8.73	Large	< 0.01*
Squat (kg)	126.1	±	21.8	165.6	±	25.1	9	39.4	(31.3%)	3.29	Large	< 0.01*
Power clean (kg)	75.0	±	14.6	95.6	±	14.2	9	20.6	(27.4%)	3.45	Large	< 0.01*
40-yard sprint (s)	5.33	±	0.13	5.26	±	0.18	10	-0.07	(-1.3%)	0.58	Medium	0.12
Pro-agility run (s)	4.79	±	0.15	4.83	±	0.35	8	0.04	(0.8%)	0.11	Trivial	0.77
Broad jump (m)	2.42	±	0.13	2.36	±	0.20	9	-0.06	(-2.4%)	0.43	Small	0.27
	Sophomore			Junior								
Age (y)	19.8	±	0.2	20.8	±	0.2	6					
Body mass (kg)	102.5	±	6.1	102.6	±	4.8	6	0.0	(0.0%)	0.00	Trivial	0.99
Bench press (kg)	122.0	±	11.5	134.0	±	12.4	5	12.0	(9.8%)	1.44	Large	0.03*
Squat (kg)	177.5	±	17.1	189.5	±	18.9	4	10.0	(5.6%)	0.88	Large	0.18
Power clean (kg)	103.1	±	13.1	111.9	±	14.3	4	8.8	(8.5%)	4.00	Large	< 0.01*
40-yard sprint (s)	5.49	±	0.39	5.41	±	0.36	6	-0.08	(-1.5%)	0.42	Small	0.35
Pro-agility run (s)	4.87	±	0.19	4.71	±	0.21	6	-0.16	(-3.3%)	0.56	Medium	0.34
Broad jump (m)	2.29	±	0.27	2.37	±	0.22	6	0.09	(3.7%)	0.51	Medium	0.28
	Junior			Senior								
Age (y)	21.0	±	0.5	22.0	±	0.5	8					
Body mass (kg)	104.5	±	5.1	108.8	±	3.6	8	4.4	(4.2%)	1.09	Large	0.02*
Bench press (kg)	131.3	±	15.1	146.3	±	15.1	8	15.0	(11.4%)	5.61	Large	< 0.01*
Squat (kg)	185.0	±	26.3	202.1	±	24.1	7	17.1	(9.3%)	0.92	Large	0.05
Power clean (kg)	102.9	±	7.0	111.4	±	10.6	7	8.6	(8.3%)	1.01	Large	0.04*
40-yard sprint (s)	5.38	±	0.31	5.33	±	0.25	7	-0.04	(-0.8%)	0.17	Trivial	0.67
Pro-agility run (s)	4.77	±	0.30	4.80	±	0.23	7	0.03	(0.7%)	0.12	Trivial	0.76
Broad jump (m)	2.39	±	0.27	2.40	±	0.21	7	0.02	(0.7%)	0.19	Trivial	0.68

Note: * $p < 0.05$.

faster despite gaining weight between their freshman and sophomore years. The skill players especially became faster between their sophomore and junior years and junior and senior years. This speed improvement seems to be specific to Japanese collegiate American football players. Theoretically, lower limb strength gains correlate with improved acceleration (44). Nevertheless, previous studies have concluded that NCAA D1 players maintain their sprint speed despite gaining weight during their first year and maintaining their weight during the second and third years (19, 25). A study of elite youth soccer players showed that resistance training intervention of the squat and the power clean improved the players' sprint speeds (32), but another study for elite youth soccer players suggested that speed improvement is minimized as the players matured, meaning that sprint speed is a valuable talent indicator for youth soccer players (15). One possible reason for our results is that speed, much like muscle strength and power, can be very trainable for Japanese American football players. Unfortunately, a valid comparison of sprint time between our results and just those previous studies is impossible because of the different measurement systems. It can be speculated, though, about the differences between our results and those from a study that revealed that top-level Japanese players were much slower (0.2–0.3 s) in the 40-yard sprint than NFL draft candidates (top-level NCAA D1 players) (41). Few reports have shown such speed improvements for highly-trained athletes (5). This study suggests that the implementation of supervised S&C programs can lead to improve sprint speed for the Japanese D1 American football players, even though the improvement may be limited in NCAA D1 counterparts.

In this study, despite the improvements in sprint speed, there were trivial to medium improvements in the other field performances; (broad jump and pro-agility shuttle), between all the annual comparisons, except for a significant improvement in the pro-agility shuttle and broad jump for the skill players between their freshman and sophomore years. An athlete's performance in the broad jump has been shown to be related to their acceleration and maximum speed in both skill and line positions (31) and the movement speed of a drive blocking in linemen (3). Therefore, it is necessary to focus on training to improve the broad jump. In addition, technical aspects that enhance COD ability should also be focused on through coaching and specific training interventions in order to apply force horizontally (6, 7, 45). These findings suggest the need for a comprehensive S&C program to optimize field performance.

There are several limitations to this study. The first was the limited sample size from a university, which resulted from injury or illness, and the research period (three years). Additionally, this study did not measure body composition and speed-time curve (or reliable acceleration assessments) during a 40-yard sprint because of equipment limitation. These assessments would provide greater insight into the effects of training and dietary programs.

PRACTICAL APPLICATIONS

This research found that over the course of three years, Japanese D1 collegiate American football skill players became stronger, more powerful, and faster. Specifically, skill players became stronger, more powerful, and faster, while linemen became heavier, stronger, and more powerful as the players' collegiate grade levels increased. These results suggest that implementing supervised S&C programs can lead to improved strength, power, and speed for Japanese D1 American football players, although the improvement in some of these aspects may be limited compared to their NCAA D1 counterparts (19, 25). However, it is important to note that the annual improvements must be carefully considered, as it is generally believed that individuals with lower initial levels of physical characteristics have a greater potential for improvement. As a result, the same absolute amount of an improvement in initially weak and strong players may represent a smaller adaptation for the former, despite greater relative improvements, and the gap between their performances may not narrow. Therefore, S&C coaches should consider making their training programs more specific and individualized as a player's training level or age increases.

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