Injury Incidence, Patterns, and Risk Factors in Functional Training Athletes in an Asian Population

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Background: Functional training, also known as CrossFit, is a unique sport that combines weightlifting, gymnastics, and metabolic conditioning into a single program. There are an estimated 50 functional training centers in Malaysia.

Purpose: To analyze the injury rates, patterns, and risk factors of functional training/CrossFit.

Study Design: Descriptive epidemiology study.

Methods: Electronic questionnaires were distributed to 244 participants from 15 centers in the country. Descriptive data regarding the athletes, injury occurrence within the past 6 months, injury details, and risk factors were collected.

Results: Of the 244 athletes, 112 (46%) developed at least 1 new injury over the previous 6 months. Injury rates were significantly higher in athletes from nonaffiliate training gyms compared with CrossFit-affiliated gyms, in athletes with previous injuries, and in those who perceived themselves as having more than average fitness.

Conclusion: Coaches and athletes need to be more aware of risk factors for injury to enable safer and better training strategies.

Keywords: functional training; CrossFit; injuries

Functional training is best described as a "continuum of exercises that teaches athletes how to handle their bodyweight in all planes of movement."[4] A form of training that uses modular movements that involve the recruitment of multiple muscle groups, functional training is the only program that combines weightlifting, gymnastics, and metabolic conditioning in 1 continuous session.

Functional training was developed and branded as CrossFit in 2002, and the terms *functional training* and *CrossFit* are often used interchangeably.[3] Called the "sport of fitness," CrossFit aims to develop broad and inclusive fitness by training athletes to a point of general physical preparedness, ready for any physical contingency.[12] Functional training/CrossFit (FT/CF) focuses on 10 physical domains: cardiovascular/respiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance, and accuracy.[6] It consists of high-intensity, functional movements that are constantly varied and programmed into workouts (commonly called the *workout of the day*).[6]

Because FT/CF is a relatively new sport, the associated injury rates and incidences are not well known. Labeled as an "extreme conditioning program," FT/CF has been often criticized, especially with regard to exercise-induced rhabdomyolysis and musculoskeletal injuries.[2,17,26] A few studies have been conducted and published, but no data on Asian populations are available.[13,21,24,26]

Malaysia has an estimated 50 FT/CF centers, the first being established in 2008. Many of these centers are nonaffiliates. CrossFit gyms are those registered with CrossFit Inc, whereas nonaffiliate gyms are those with similar

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training methods and programs but not officially registered with CrossFit.[7] Over the past 12 years, FT/CF has increased rapidly, and national-level competitions are held at least once a year. This Malaysian-based study investigated the incidence and risk factors of FT/CF-related injuries and examined injuries in both affiliated and nonaffiliated gyms, an aspect not studied in previous literature. These findings should aid in the evidence-based participation in FT/CF and provide better understanding of the risks involved.

METHODS

Convenience sampling was conducted via an online questionnaire using Google Forms that was distributed to FT/CF gyms in Malaysia. The questionnaire was adapted from a previous study by Mehrab et al[21] based in the Netherlands. Coaches from each FT/CF gym were briefed personally to enable better consistency of answers by the athletes.

Inclusion criteria were athletes from FT/CF gyms aged 18 years and older who understood English. We excluded those who had significant physical challenges (eg, limb amputation, paraplegia) and those with preexisting medical conditions that impaired independent ambulation. This is because some FT/CF facilities offer adaptive training programs designed for people with disabilities. All injuries and diagnoses were self-reported and were not verified by a physician.

Using the calculator for prevalence studies provided by Naing et al,[22] we determined that the sample size needed was 237 athletes for a precision of .05 and an injury rate of 19% from previous studies. Outcomes were the occurrence of injury within the past 6 months of training, association with factors such as previous injury, presence of the coach, certification of the coach, type of gym, and self perceived level of fitness. An injury was defined as a new musculoskeletal pain, sensation, or discomfort that resulted in any of the following[26]:

- Total removal from CrossFit training and other outside routine physical activities for >1 week
- Modification of normal training activities in duration, intensity, or mode for >2 weeks
- Any physical complaint severe enough to warrant a visit to a health professional

Injury rates were reported as the percentage of new injuries per person during training sessions, whereas injury incidence rates were reported as the number of injuries per 1000 hours of training exposure.

Previous injury was defined as any type of injury defined as above but that resolved before the participant answered the questionnaire. Duration of training hours was divided into 4 categories: <30 minutes, 30-60 minutes, 1-2 hours, and >2 hours. The average time of 15 minutes, 45 minutes, 90 minutes, and 120 minutes was taken to calculate total training hours. Body mass index (BMI) categories were classified according to local guidelines.[19] Fitness level was explained to athletes as their own self-perception of their fitness level.

TABLE 1
Descriptive Data and Training Details

Injured in past 6 months, n (%)	
Yes	112 (46)
No	132 (54)
Age, y, mean ± SD	33.2 ± 6.922
Age by group, n	
≤30 years	93
31-40 years	105
≥41 years	36
Sex, n (%)	
Male	117 (48)
Female	127 (52)
Body mass index, kg/cm^2, mean ± SD	24.8 (3.73)
Body mass index by group, n (%)	
<18.5 kg/cm^2	2 (0.8)
18.5-22.9 kg/cm^2	82 (33.6)
23-27.4 kg/cm^2	112 (45.9)
≥27.5 kg/cm^2	48 (19.7)
Training frequency, n (%)	
1 time per week	5 (2)
2 times per week	18 (7.4)
3 times per week	59 (24.2)
4 times per week	66 (27)
5 times per week	68 (27.9)
6 times per week	22 (9.0)
7 times per week	6 (2.5)
Fitness level, n (%)	
Completely unfit	32 (15)
Not very fit	58 (24)
Average	129 (49)
Fit	15 (12)
Gym location, n (%)	
East Malaysia	156 (63.9)
West Malaysia	88 (36.1)
Training duration, n (%)	
<6 months	34 (13.9)
6 months to 1 year	36 (14.8)
1-2 years	52 (21.3)
2-3 years	107 (43.9)
>3 years	15 (6.1)
Session duration, n (%)	
<30 minutes	9 (3.7)
30-60 minutes	110 (45.1)
1-2 hours	107 (43.9)
>2 hours	18 (7.4)
Coach-client ratio, n (%)	
<5 clients per coach	36 (14.8)
5-10 clients per coach	148 (60.7)
>10 clients per coach	60 (24.6)
Coach present, n (%)	
Yes	221 (90.6)
No	23 (9.4)
Objective of participation, n (%)	
Overall fitness	210 (86.1)
Competition	34 (13.9)

Descriptive data were expressed as means, and categorical data were expressed as frequencies and percentages. Means and standard deviations were reported in the summary statistics. Data were analyzed with SPSS software

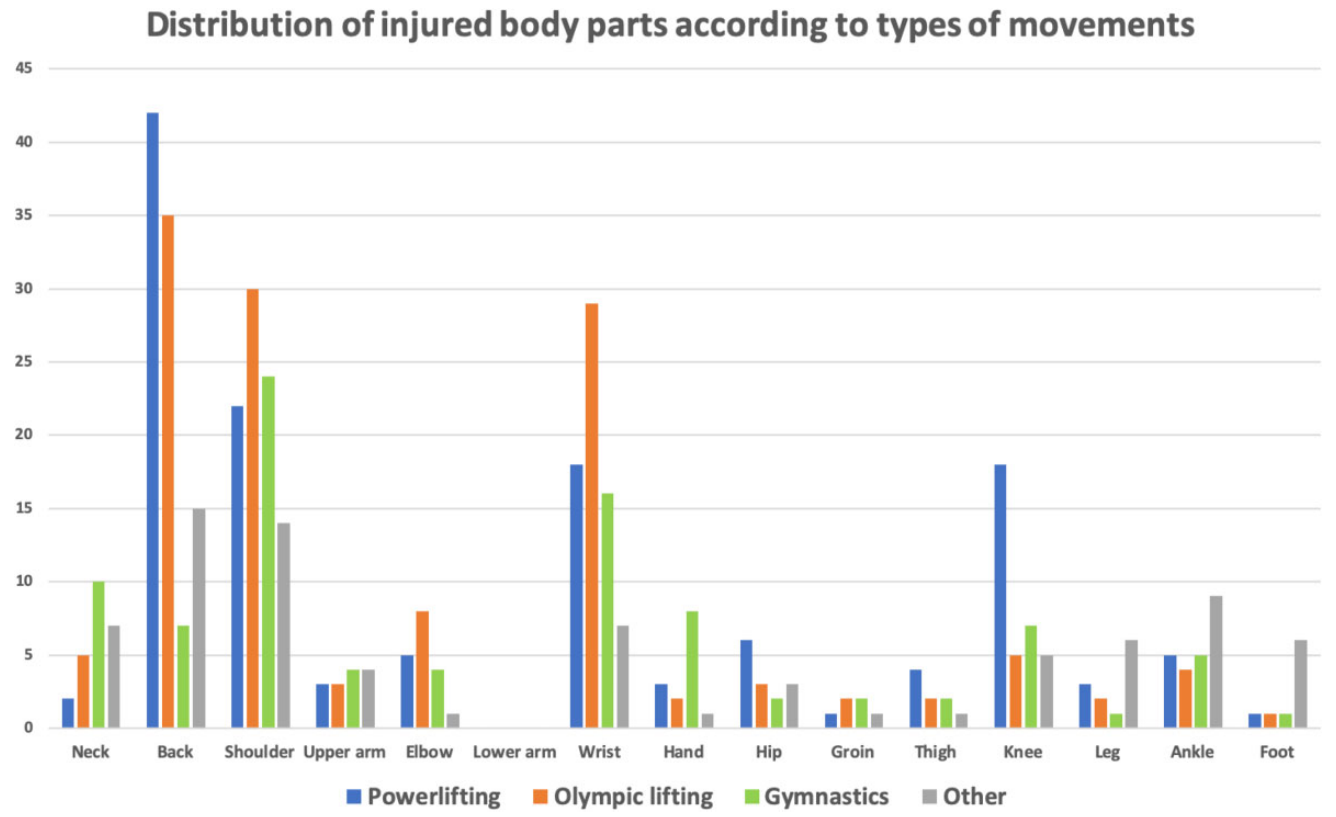

Figure 1. Distribution of injured body parts according to type of movements.

Version 23. The chi-square test of independence was used to test the relationship between various factors and the occurrence of injuries. Multiple binary logistic regression was used for a multivariable analysis of the factors significantly related to injury occurrence.

The study obtained ethical approval from the Malaysian Medical Research and Ethics Committee and was in line with international ethics guidelines.[14] No respondent identifiers were collected.

RESULTS

Questionnaires were distributed to 35 FT/CT centers, with an estimated 1500 members in total. A total of 244 respondents from these centers (117 men and 127 women) answered the online questionnaire (response rate, 16%). Descriptive data and other details of respondents are as shown in Table 1.

We found that 112 respondents were injured at least once in the preceding 6 months, for an injury rate of 46% (112/244). Overall injury incidence was 5.3 injuries per 1000 hours. Women had a lower injury incidence (5.1 injuries per 1000 hours) compared with men (5.5 injuries per 1000 hours). Of the 244 respondents, 150 (62%) trained at a CrossFit affiliate, whereas 94 (39%) trained at a nonaffiliated gym. In affiliate gyms, 53 athletes (35%) were injured and 97 athletes (65%) were not; in nonaffiliate gyms, 59 athletes (63%) sustained new injuries and 35 (37%) did not. More than 50% of respondents believed their fitness level was above average. Those with higher levels of perceived fitness sustained more injuries than those who perceived themselves as less fit.

A total of 194 (80%) athletes had no prior injuries before the study, whereas 50 athletes (21%) had injured themselves in the past and had recovered. Of these 50 athletes, 30 (60%) athletes with previous injuries developed new injuries and 20 (40%) did not; 82 (42%) athletes with no previous injuries developed new injuries and 112 (58%) did not. Overall, 437 body parts were injured, and data were collected according to types of movements causing the injuries (Figure 1). Powerlifting was defined as the deadlift, back squat, and bench press; Olympic lifting was the snatch and the clean and jerk; gymnastic movements were burpees, pull-ups, muscle-ups, and all other bar or ring movements; and other movements included kettlebell movements, thrusters, skipping, Turkish getups, and those not in the previous 3 categories.

Chi-square tests of independence were performed to examine the relation between the occurrence of injury and the different characteristics listed in Table 2 (N = 244). The factors that had a significant association with injury rates were the type of FT/CF center ($\chi^2 = 0.324$; $P < .001$), the presence of previous injury in athletes ($\chi^2 = 0.488$; $P = .027$), and athlete's self-perceived level of fitness ($\chi^2 = 11.1$; $P = .01$). In an analysis of factors influencing the injury incidence and rates in our study, logistic regression showed an increased risk of injury occurrence in nonaffiliated gyms

TABLE 2
Relationship Between Injury and Respondents' Characteristics According to Bivariate Analysis

Characteristic	Injured, n (%)	Not Injured, n (%)	χ^2	*P* Value
Age			0.85	.65
≤30 years	48 (43)	55 (42)		
31-40 years	50 (45)	55 (42)		
≥41 years	14 (12)	22 (16)		
Sex			0.348	.555
Male	56 (50)	61 (46)		
Female	56 (50)	71 (54)		
Body mass index			0.483	.785
≤22.9	36 (32)	48 (36)		
23-27.4	53 (47)	59 (45)		
≥27.5	23 (21)	25 (19)		
Previous injury			0.488	.027
Yes	30 (27)	20 (15)		
No	82 (73)	112 (85)		
Gym type			0.324	<.001
CrossFit affiliate	53 (47)	97 (74)		
Nonaffiliate	59 (53)	35 (26)		
Gym location			3.913	.048
East Malaysia	79 (71)	77 (58)		
West Malaysia	33 (29)	55 (42)		
Fitness level			11.1	.01
Completely unfit	17 (15)	25 (19)		
Not very fit	27 (24)	31 (24)		
Average	55 (49)	74 (56)		
Fit	13 (12)	2 (1)		
Duration of training			5.372	.251
<6 months	12 (11)	22 (17)		
6 months to 1 year	22 (20)	14 (11)		
1-2 years	25 (22)	27 (20)		
2-3 years	47 (42)	60 (45)		
>3 years	6 (5)	9 (7)		
Session duration			1.735	.629
<30 minutes	4 (4)	5 (4)		
30-60 minutes	46 (41)	64 (48)		
1-2 hours	52 (46)	55 (42)		
>2 hours	10 (9)	8 (6)		

(odds ratio [OR], 3.085; $P < .05$). However, no significant difference was found between injuries in FT/CF centers located in East versus West Malaysia ($\chi^2 = 3.913$; $P = .048$) (OR, 0.778; $P = .41$). Athletes who perceived themselves as having above-average fitness were almost 10 times more likely to develop an injury (OR, 9.936; $P = .008$).

A multiple logistic regression built using statistically significant factors in the bivariate analysis was used to predict injury occurrence based on gym type, gym location, presence of previous injuries, and self-perceived fitness levels (Table 3).

DISCUSSION

This study reported an FT/CF-related injury rate of 46% (112/244). This is comparable with rates published by other studies, which range from 19% to 74%. The wide range of injury rates can be attributed to the many variables involved in FT/CF training, such as the type of workouts

TABLE 3
Multiple Binary Logistic Regression Analysis of Injuries and Possible Risk Factors

Variable	*P* Value	Odds Ratio	95% CI
Gym type			
Nonaffiliate		Reference	
Affiliate	.026	3.085	1.766-5.388
Gym location			
East Malaysia		Reference	
West Malaysia	.41	0.778	0.428-1.414
Previous injury			
No		Reference	
Yes	.026	2.147	1.095-4.210
Fitness level			
Completely unfit		Reference	
Not very fit	.648	1.216	0.525-2.818
Average	.736	1.137	0.541-2.389
Fit	.008	9.936	1.788-49.367

TABLE 4
Injury Rate According to Type of Sport

Lead Author (Year)	Type of Sport	Injury Rate, %
Weisenthal[26] (2014)	CrossFit	19
Hak[13] (2013)	CrossFit	74
Mehrab[21] (2017)	CrossFit	56.1
Sprey[24] (2016)	CrossFit	31
Van Gent[25] (2007)	Long-distance running	20-79
Sousa[23] (2013)	Soccer on artificial turf	56
Del Vecchio[8] (2018)	Martial arts/combat sports	53.6
Current study	Functional training/CrossFit	46

and the physical backgrounds of the athletes involved.[26] Self-reporting of injuries was shown to be accurate in a previously validated study by Gabbe et al,[11] indicating a 100% recall of the presence of injuries.

Our injury rate is similar to that reported by Mehrab et al,[21] as we adopted the same definition of injury (Table 4). Hak et al[13] defined *injury* as "any injury sustained during training that prevented the participant from training, working or competing in any way and for any period of time." This nonspecific definition could explain the high injury rate reported in their study. The 46% injury rate that we found is also comparable with injury rates in other sports. Martial arts and combat sports had an injury rate of 54%,[8] whereas a systematic review of 17 articles on long-distance running showed this activity to have a wide range of lower extremity injury rates—20% to 79%.[25]

The overall injury incidence rate in our FT/CF study of 5.3 injuries per player per 1000 hours is higher than rates reported in gymnastics (1.6) and badminton (2.9) but lower than the rate in soccer (8.0) (Table 5).[1,15] This is most likely due to the nature of soccer being a contact sport, whereas the other 3 sports are not. Amateur soccer players on artificial turf, however, recorded an injury incidence rate of 5.1 injuries per player per 1000 hours.[23]

TABLE 5
Injury Incidence Rate According to Type of Sport

Lead Author (Year)	Type of Sport	Injury per Player per 1000 h
Sousa[23] (2013)	Soccer	5.1
Jørgensen[15] (1987)	Badminton	2.9
Eberhardt[9] (2007)	Bodybuilding	1.0
Bak[1] (1994)	Gymnastics	1.6
McLennan[20] (1990)	Highland games	7.5
Ekstrand[10] (2011)	Professional football	8.0

Weight training is a major component of FT/CF. Keogh et al[16] reviewed 18 articles on weight training sports and found an injury incidence rate of 1 to 7.5 injuries per 1000 hours; bodybuilding had the lowest rate (1.0 injuries per 1000 hours) and highland games the highest (7.5 injuries per 1000 hours). Bodybuilding is a sport that involves weight training but has minimal sudden movements, jerks, or pivots that can contribute to injury; highland games involve the lifting of extremely heavy objects such as tires and the pulling of loads >1000 kg in weight, thus explaining the high injury incidence.[20]

The significantly lower injury rates in affiliated versus nonaffiliated FT/CF gyms could be due to the monitoring and supervision by CrossFit headquarters. This affiliation might also standardize the type of coaching and movement standards, therefore more effectively preventing injury. The lack of significant difference between injuries in FT/CF centers located in East and West Malaysia suggests that the method of training and level of supervision are similar regardless of the location of the center (Tables 2 and 3).

Athletes with previous injuries must take precautions such as longer warm-up periods and modified movements before undergoing FT/CF training, as our analysis suggested that a prior injury renders the athlete susceptible to further injuries (Tables 2 and 3). The perception of one's fitness level can lead to underestimation of the training program, lack of proper warm-up, or both, hence leading to more injuries; our analysis indicated that athletes who perceived themselves as being fit had 10 times the increased risk of injury (Tables 2 and 3).

Injuries to different body parts according to type of movement revealed a high rate of back injuries in the powerlifting and Olympic lifting movements, followed by the shoulder and the wrist (Figure 1). This is an important reminder to the coach and athlete to ensure proper warm-up sessions and take necessary precautions during workout programs. These findings are consistent with the results of other studies in Western populations.[21,26] Our data also revealed that the most frequently injured body part in gymnastic movements was the shoulder, in accordance with a study on gymnastics injuries.[5]

The injury rates were not significant across the duration/frequency of training, indicating that beginners and experienced athletes have the same risk for injury. This finding was attributed to the close supervision of athletes by coaches, which is unique to FT/CF and seldom practiced in conventional or commercial bodybuilding gyms.[6] It also suggests that FT/CF athletes can train regularly, even up to 7 days a week, without significant risk of injury.

In this study, 112 (45.9%) athletes were overweight and 48 (19.7%) were obese. Age, sex, and BMI of athletes were not associated with injury rates. This highlights the inclusivity of FT/CF and the adaptability of the programming to participants regardless of fitness background, body weight, and size. Known as "adaptive training," this easily modifiable aspect of FT/CF makes it suitable for people with disabilities and those with previous neurological insult.[18]

Besides providing physical fitness benefits, FT/CF gives athletes an increased sense of community, satisfaction, and motivation.[6] More research is needed in functional training in the Asian population. Self-reporting of injuries and recall bias were among the limitations of this study. The variability of workout programs and coaching styles between different gyms could also affect the pattern of injuries faced by athletes. Another limitation of our study was that only about 16% of potential participants replied. Therefore, it is uncertain whether the reported prevalence of injury reflects the actual prevalence within the entire population.

CONCLUSION

This is the first study of its kind in an Asian population, and our results are similar to studies conducted in Western populations; this suggests that FT/CF is an inclusive sport and is safe for all, regardless of age, sex, BMI, or ethnicity.[13,21,24,26] We found that FT/CF has similar injury incidence rates compared with other sports and therefore does not pose an increased risk of injury.

The significance of association between injury rates and the type of gym (CrossFit–affiliated vs nonaffiliated) could guide athletes in deciding where to train. To prevent injuries, adequate warm-up of the back and shoulder must be performed, and extra precautions must be taken both by those who are new to the sport and by athletes with prior injuries.

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