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Bodyweight Training for Muscular Strength & Endurance

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Abstract

The COVID Pandemic and cost of living crisis have created renewed interest in home gymnasiums, and outdoor exercise regimes as the stay-at-home economy continues to grow. Emerging from the revolution in stay-at-home exercise has renewed interest in bodyweight exercise training regimes which have stood the test of time against conventional exercise modalities. This mini review highlights the benefits of bodyweight exercise to develop muscular strength and endurance and provides recommendations on using bodyweight training to improve muscular strength and endurance.

Keywords: Bodyweight training; Strength; Endurance; Calisthenics; Relative strength

Trends in Bodyweight Training

The COVID pandemic has decreased reliance on gym and fitness equipment-based routines. As a result, much of the population has become more motivated to continue exercising at home [1]. By way of example, surveys conducted since the COVID pandemic show only 30% of gym members have returned since covid [2]. Moreover, home exercise gyms, online exercise classes and outdoor activities such as hiking, climbing, and running are increasingly popular as consumers look to reduce discretionary spending due to the increased cost of living pressures [3,4]. Together, these research and survey data suggest that consumers are looking at innovative ways to stay fit and active in the home environment.

With a move away from gymnasium-based exercise training, there has been growing interest in programs performed with little or no equipment, such as bodyweight training [3,5]. In contrast to externally loaded resistance training, bodyweight training maximizes relative strength while promoting spatial awareness and gross movement competency [6]. The origins of bodyweight training can be traced back to the early days of human civilization; Our ancestors used their bodies to perform various tasks, from hunting and gathering to farming and building shelter [7]. This type of physical activity helped them stay fit and healthy and served as a form of recreation. As time went on, bodyweight training became increasingly formalized. The ancient Greeks and Romans developed elaborate exercise systems using their body weight. Historical records suggest that bodyweight exercise was used by the armies of Alexander the Great and the Spartans [7]. In more recent times, bodyweight training has been popularized by several different people and groups, including the physical culturists of the early 20th century, the military, and the counter-culture movements of the 1960s and 1970s. The benefits of bodyweight training include improved muscle tone, increased strength and endurance, improved joint stability, cardiovascular fitness and increased flexibility [6,8-11].

Benefits of Bodyweight Training

Bodyweight exercises are divided into two main categories: callisthenics and bodyweight strength training. Callisthenics are exercises that use your body weight and gravity to provide resistance, such as push-ups, sit-ups and squats. In contrast, bodyweight strength training uses equipment such as swiss balls, wearable resistance garments, resistance bands, or TRX suspension trainers [6]. Unlike bodyweight training, gymnasium-based strength training incorporates many open-kinetic chain exercises [6]. Open kinetic chain (OKC) exercises are exercises in which the distal extremity is free to move in space, which is characterized by a rotary stress pattern to the joint [12]. For example, when doing a biceps curl with a dumbbell, your hand holding the weight is free to move throughout the range of motion. This exercise allows for a greater range of motion and isolation of specific muscles, making it ideal for isolating muscles

for hypertrophy training. However, because the distal extremity is not stabilized, OKC exercises may not be suited for particular rehabilitation objectives, such as improving balance [13].

In contrast to gymnasium-based exercise, bodyweight exercises are performed in a closed-kinetic chain (CKC) pattern. Closed kinetic chain exercises are exercises in which the distal extremity is fixed [12]. An example of this would be a squat, where the feet are planted firmly on the ground throughout the entire movement. This type of exercise is often used in sports training as it better simulates the movement patterns in many sports [12,14]. It also requires more stabilizing muscles, making it ideal for strengthening the core and preventing injuries. However, because the range of motion is more limited, it may not be suitable for those with existing injuries.

Bodyweight training has many advantages and should not be considered the panacea for all health and fitness-related goals. For instance, bodyweight training may not match the absolute strength (the ability to move an absolute amount of load) gains achieved from free-weight or machine training [6,15]. However, research suggests that adding resistance bands to bodyweight strengthening exercises such as push-ups can rival the absolute strength improvements of barbell training [16]. Furthermore, the load in bodyweight exercises such as push-ups approach 75% of body weight [17], which for a 100-kilogram individual would equate to a 75-kilogram lift each repetition. Such loads are likely to meet established guidelines for the development of strength [18].

On the other hand, bodyweight training develops relative strength (the ability to move a load, as a certain percentage of body weight) and cardiovascular endurance. By way of example, researchers from McMaster University, Canada, reported significant improvements in aerobic fitness in a group of healthy, inactive adults after completing an 11-minute bodyweight circuit training program for six weeks. Other researchers have reported similar improvements in aerobic fitness from bodyweight circuit training [8,10]. Taken together, these data suggest bodyweight training benefits the development of relative strength and aerobic fitness. Improvements in absolute strength over time may be difficult and overcome by adding external resistance or progressing to single-limb variations.

Principles of Bodyweight Training

Akin to the conventional strength training guidelines [18], bodyweight training for enhancing muscular strength should follow similar principles, with a few important caveats. Firstly, the assumption that bodyweight exercises are easy must be addressed to avoid potential injury. Most beginners do not possess the requisite levels of strength to lift their bodyweight in a chin-up or dip, two common bodyweight exercises for the upper body. Nor may they in common bodyweight exercises for the legs, such as a squat; for the average person, the thighs make up 11% and the trunk 54% of their body weight [19]. This means they will be lifting approximately 60-70% of their superincumbent body weight each repetition, which is more than enough to cause excessive muscular soreness if the starting number of sets and repetitions is too high. Thus, for heavier individuals, bodyweight exercise becomes more demanding on the musculoskeletal system.

Secondly, the spinal compressive forces need to be taken into account. Bodyweight exercises such as push-ups, supine pull-ups, back raise, and planks position the spine in a perpendicular position against gravity, which can create tremendous compressive forces on the spine. These compressive forces can easily exceed the tissue tolerances of the spine and lead to injury. For example, the National Institute for Occupational Safety & Health (NIOSH) recommends spinal compression forces never exceed 3,400 newtons [20]. Repetitive exposure to compression loads above this level is associated with injury (McGill, 2015). A single-arm push-up imposes 5,484 newtons of compression [21], whereas popular core strengthening exercises, such as sit-ups, impose 3,506 newtons of compression on the spine. Collectively, these compression penalties warn unsuspecting fitness enthusiasts that certain variations of popular bodyweight exercises, such as push-ups and sit-ups, can present a real risk of injury to the spine. Further examples of the compression loads in various bodyweight exercises can be seen in Table 1.

Finally, the level of muscle activity must be considered if there is a desire to use bodyweight training to increase strength. Electromyographic analysis (EMG) determines muscle activity in different exercises. (Ekstrom) EMG is normalized and expressed as a maximum voluntary isometric contraction (MVIC). For an exercise to provide sufficient stimulus to improve strength improvement, MVIC values should be >45%. In contrast, MVC values that are <45% are beneficial for motor control training or for improving muscle endurance. Examples of Muscle activity and MVIC values for different bodyweight exercises can be seen in Table 1.

Notwithstanding these considerations of excessive loading and spinal compression penalties, bodyweight training, as an alternative to conventional, gymnasium-based exercise, can target and improve components of fitness, such as strength, muscle endurance, cardiovascular fitness and flexibility. Notably, body weight training should adhere to the general principles of exercise program design which includes the following acute training variables, described by Hayes et al. [30].

a) Choice of exercise: select bodyweight exercises that utilize the major muscle groups. According to the minimal dose approach for resistance training [31-33], As little as 2-exercises per major muscle group can improve strength and functional ability in younger and older adults [31]. Therefore, the choice of exercises should be based on training status, goals and time constraints.

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Table 1: EMG, MVIC and Compression loads in different bodyweight exercises

Variation	MVIC %	Spinal Compression (N)	Muscle Activity
Side plank on knees			RA [22]
			EO [22]
			ES [22]
Side plank on knees with abduction			
Glute Bridge	ES 39% [23]		LM [24]
	GMed 28% [23]		
	GM 25% [23]		
Plank on toes	EO 47-76% [23,25]	1600-1800 [26]	RA [24,27]
	IO 58% [25]		EO [24,27]
	RA 43% [23]		ES [24,27]
Plank on toes with hip extension	GM 106% [28]		
	GMed 75% [28]		
Push-up Plank		1,838 [21]	AD [23]
			RA [23]
Side plank on toes	EO 69% [23]	2,500 [21]	
	RA 34% [23]		
	LM 40-42% [23]		
	GM 74% [23]		
Rotational side plank	EO 60-62% [29]		
	RA 36-43% [29]		
	GMed 46-71% [29]		
	ES 36-46% [29]		
	LM 14-30% [29]		
4-point kneeling with hip extension		2,000 [21]	
Bird / dog	LM 36% [23]	3,000 [21]	
	ES 46% [23]		
	GMed 42% [23]		
	GM 56% [23]		

Key: MVIC = Maximal Voluntary Isometric Contraction, IES=Erector Spinae, LM = Lumbar Multifidus, EO=External Oblique, IO=Internal Oblique, RA=rectus abdominis, GMed=Gluteus Medius, GM=Gluteus Maximus, HS=Hamstrings, AL; Adductor Longus, LD= Latissimus Dorsi, PM= Pectoralis Major, AD= Anterior Deltoid, SA=serratus anterior, TB=Triceps Brachii

b) Order of exercise: large muscle groups before small muscle groups to maximize the expression of strength. The following program (Table 2) demonstrates how the principle of exercise order can be applied to bodyweight training.

c) Load: The American College of Sports Medicine Position Stand on Progression Models in Resistance Training [18] recommends that workouts cycle training loads equivalent to 80-100% 1RM to maximize muscular strength and 70-100% of 1RM to maximize hypertrophy. More recent research suggests that loads (>30% of 1RM) can stimulate improvements in muscular strength and hypertrophy [34]. For bodyweight training focusing on strength, a load can be applied by changing the starting position or adding external objects such as resistance bands. Alternatively, the load of different bodyweight exercises can be estimated from known anthropometric data on the weight of varying body segments [19]. To determine which body segments, contribute to the load, add the weight of each body segment involved that moves upward against gravity during the exercise.

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d) Volume (sets x reps x load): The minimal dose approach should be considered for beginners and time-poor individuals. According to this theory [31,33], improvements in muscular performance can be achieved from as little as two sets per exercise, which means the exercise session can be completed in as little as 15-minutes. On the other hand, making gradual increases in volume and gradual decreases in intensity is an effective training method to increase muscular (Table 3) endurance [35].

e) Rest period between sets Conventional guidelines, such as those provided by The ACSM [18], recommends 2–3-minute rest periods between sets, for conventional strength training approaches. In contrast, circuit training approaches require minimal rest between sets or exercises, which has also been shown to produce modest improvements in strength [36]. Collectively, bodyweight training focusing on strength development should use longer rests and, for muscle endurance, minimal or no rest at between sets or exercises if the program is designed in a circuit format.

f) Progressive overload Conventional resistance training guidelines recommend increasing resistance levels by 10% per week [18]. Bodyweight training programs need to compensate for the lack of external resistance by adjusting other acute training variables (sets x reps) and biomechanical factors such as: increasing the total number of repetitions, adding multiple sets, completing repetitions for time, speed and tempo manipulations, varying the base of support, lever manipulation and changing the starting position such as switching from a base position on the floor to an incline or decline position [15].

Table 2: Bodyweight Circuit Complete as a circuit, beginners 1-2 rounds, intermediate 2-3 and advanced 3-5 rounds. Rest 1-2 minutes between rounds.

Exercise	Progressions	Regressions	Reps	Tempo
Squat	Single leg	Wall squat	15-Dec	2:01:02
Lunge	Bulgarian Lunge	TRX lunge	15-Dec	2:01:02
Supine pull-up	Chin up	Band-assisted pull-up	15-Dec	2:01:02
Push-up	Incline push up	Wall or knee push-up	15-Dec	2:01:02
Pike-Push up	Handstand push up	Pike push up on the bench	15-Dec	2:01:02
Bench Dips	Bar dips	Bench dip with knees bent	15-Dec	2:01:02
TRX Bicep Curls	Single-arm TRX bicep curl	Isometric bicep curls	15-Dec	2:01:02
Calve Raises	Single leg calve raises	Isometric calve raises	15-Dec	2:01:02
Plank	Push-up plank	Plank on a bench or kneeling	60-seconds	

Table 3: Minimal Dose Resistance Training Guidelines [31].

	Traditional Resistance Training (RT)	Minimal Dose RT
The number of exercises and sets per muscle group.	2-3 exercises per muscle group	<2 exercises per muscle group
	2-4 sets per exercise	< 2 sets per exercise
Session duration	45 minutes +	<15-minutes
Sessions per week	2-3 sessions per week	5-7+ sessions per week
Load	30-70% 1-repetition maximum (1RM)	Bodyweight to <30% 1-RM
Equipment Requirements	Traditional equipment	Minimal/no equipment
	barbells, dumbells, machines	Bodyweight, resistance-bands

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Conclusion

Bodyweight training is a versatile mode of exercise that continues to grow in popularity due to the lasting effects of the COVID pandemic and cost of living pressures. When safety considerations such as the percentage of body weight as load and spinal compression are taken into consideration can produce favorable outcomes in both strength and endurance. Although bodyweight training may look simple, proper attention to technique and starting exercise selections will ensure training remains safe and enduring. However, the purpose of this article is not to downplay the well-established benefits of conventional strength training, as both methods can be complementary and yield optimal results in health and fitness.

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