Analytical classification of body weight exercises according to the topological criterion

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Abstract:

Body weight exercises represent the most accessible way to improve muscle strength, power, and other motor abilities. Many muscles are simultaneously involved in performing body weight exercises. **Problem statement:** How to classify body weight exercises according to the topological criterion? **Approach:** The subject of this paper was the analytical classification of body weight exercises based on the topological criterion. The aim of this paper was to describe, analyze and classify the basic body weight exercises from the basic set according to the topological criterion. In the paper was used a method of descriptive analytical classification consisted of four steps. In the first step, a review of various information sources was performed. The basic set of exercises was defined in the second step. In the third step, the criterion for classifying the exercises was chosen. The type of exercise classification is determined in the fourth step. **Purpose:** The purpose of this paper was to create a clear overview of body weight exercises as a basis for successful training planning and programming. **Results:** By analyzed body weight exercises according to the topological criterion, exercises were classified into three classes shown in the tables. A total of 68 exercises were classified; for the upper body, 26 exercises were classified, 22 for the middle body ("core"), and 20 for the lower body. **Conclusions:** All body weight exercises from the basic set were classified according to the topological criterion regarding the exercise's primarily engaged muscle and body parts. The dichotomy occurred when the exercise was topologically represented in both classes and when exercise was performed as one movement but required the primary engagement of two subclasses. The presented classification of body weight exercises according to the topological criterion can serve as a basis for planning and programming training of different needs and goals.

Keywords: strength training, power, class, subclass

Introduction

Body weight training involves performing exercises in which the load is only the body weight and equipment such as horizontal bar, push-up handles, parallel bars, jumping rope, which does not change body weight but allows better performance of the exercises. Body weight exercises are one of the most accessible and most used in training. Many sports branches are based on performing movements where the load represents one's own body, such as gymnastics, kicking and punching martial arts, athletic running and jumping disciplines, and sports games. Here, an important role has relative muscle strength, which is defined as the ratio of maximum muscle strength and body mass (Fukuda, 2019). According to the results of the American College of Sports Medicine (ACSM) questionnaire, body weight training took first place among fitness trends in 2015, and in 2021 it took third place (Thompson, 2014; 2020). Also, in 2021, body weight training, as a type of load and method, takes first place, given that high-intensity interval training (HIIT – High-Intensity Interval Training) is in fifth place, and strength training with free weights (bars, kettlebells, dumbbells, medicine balls) in eighth place.

There are various motives for body weight training such as: improving motor abilities (strength, power, speed, coordination, mobility, endurance, and agility), morphological characteristics (body composition), health status, influencing the proper growth and development of children, socialization, acquisition of healthy habits, prevention and rehabilitation of injuries, and the exercise of the elderly. Within motor abilities, there is evidence that body weight exercises are useful for beginners, for reviewing basic movement patterns and planning athlete training programs, improving muscle strength, power, body composition, and posture (Kritz et al., 2009; Kritz et al., 2010; Kotarsky, 2018; Klisarić, 2020; Guerra et al., 2019; Thomas et al. 2017; Cigerci & Genc, 2020). The Long Term Athlete Development (LTAD) model recommends that children perform exercises and activities based on the load on their body mass to improve muscle strength (Balyi et al., 2013). These can be body weight exercises, such as squats, lunges, one-leg squats, push-ups, dips, pull-ups, inverted row, "core" exercises, etc.

In order to achieve the stated benefits and desired goals, it is necessary to make an appropriate training program with body weight exercises. Quality planning and implementation of training programs require much will, effort, knowledge, and other resources. In planning and programming strength training, adequate modification of basic training variables should be the starting point (Ranisavljev & Ilić, 2010). Also, one of the most crucial starting variables of the training program is the choice of exercises (Baechle & Earle, 2012). The

choice and the exercise order in the training program affect the improvement of the organism's abilities and desired adaptations.

Engagement of the body parts and muscles can be different depending on the performance conditions of the exercises. In the gym, numerous weights and machines are constructed to engage specific muscles, and it is easier to determine which muscles are engaged during the exercises. Most machines in the gym require a fixed movement pattern that adjusts muscle engagement. Apart from the gym, many diverse body weight exercises do not strictly follow fixed movement patterns. However, muscle engagement in body weight exercises depends mostly on body positions during the movements. Various exercises can engage different muscles, activation levels, and loads in body weight exercises (Schoenfeld, Contreras, Tiryaki-Sonmez, Willardson, & Fontana, 2014; Suprak, Dawes, Stephenson, 2011; Ebben, Wurm, VanderZanden, Spadavecchia, Durocher, Bickham, & Petushek, 2011).

Besides mentioned, there are many other aspects to consider when performing body weight exercises. A widely accepted strategy in resistance training is to use both eccentric and concentric contractions (Hody et al., 2019). Eccentric muscle work can improve the size and strength of the muscles and the quality of the tendon spring (LaStayo et al., 2003). According to Schoenfeld (2020), concentric and eccentric contraction activate muscle fibers differently and create different morphological adaptations, so both types of contractions should be included in the training to maximize muscle hypertrophy. Then, many body parts and muscles are simultaneously involved in performing body weight exercises. However, isolation body weight exercises are possible.

Some body weight exercises, although very similar, can vary the intensity of the engagement of the muscles. For example, performing body weight exercises with one limb increases the intensity of the exercise and generally requires the "core" to act anti-rotational, making the exercises more challenging. In addition, according to Bompia and Buzzichelli (2019), muscle balance is achieved by frequent and greater use of unilateral than bilateral exercises. Also, the angle at which muscle fibers act against the force of gravity determines their engagement (Schoenfeld, 2020). Adequate knowledge of different push-ups can engage the desired musculature (Contreras et al., 2012). For example, push-ups require the dominant engagement of the pectoral muscles. However, they are at a lower intensity than the handstand push-ups which require the dominant engagement of the shoulder muscles.

In Gray's anatomical atlas, Drake and colleagues (2020) present body parts and muscle groups as follows: whole body (front and back muscles), back, superficial, medium, and deep musculature), thorax (chest muscles, chest muscles, and diaphragm), abdomen (abdominal wall muscles), pelvis (pelvic muscles), lower extremities (buttocks, thighs, lower legs, and feet), upper extremities (forearms and hands), head and neck (neck and head muscles). Drake and colleagues (2020) provide a detailed anatomical insight into the division of body parts and muscle groups. The head muscles responsible for eye movements are not involved (directly) in strength and power training so they can be excluded from the classification. In training practice, depending on the needs and goals, certain parts of the body are used to a greater or lesser extent.

It is necessary to point out that the "core" has its anatomical structure, including a part of the body with its active and passive components (bones, muscles, joints, and connective structures). According to Willardson (2014), the "core" consists of a total of 22 muscles, and some are divided into groups (so there are more), of which: six global "core" stabilizers, six local stabilizers, six responsible for the transfer of movement to the upper extremities and four responsible for transfer to the lower extremities. The basic movement patterns of the "core" are flexion, extension, rotation, and lateral flexion. The stabilization positions of the "core" are derived from its basic movement patterns: anti-flexion, anti-extension, anti-rotation, and anti-lateral flexion. Thus, the "core" has two main functions: stabilizing the trunk and transferring the movement to the upper or lower extremities. Therefore, the "core" can be viewed as a functional set of anatomical structures that act together or segmentally (in isolation) to perform their role in a given exercise.

When describing the exercises, the topological criterion is often used, according to which the exercises are classified in relation to engaged body parts and muscle groups. For example, Kukolj (2006) classifies exercises into exercises for the development of arm and shoulder girdle muscles, trunk, and legs. Then, Ranisavljev and Ilić (2010) classify basic strength and power exercises into exercises for the whole body, lower body, upper body, and "core." Further, strength training exercises can be grouped according to the muscles involved in the movement, such as abdominal exercises and leg exercises (Zatsiorsky et al., 2020).

Many authors classify strength exercises differently concerning different parts of the body and muscle groups. Haff and Triplett (2016) divide exercises in weight training into exercises for the abdomen, back, chest, shoulders, biceps, triceps, forearms, hips and thighs, calves, and strength exercises (Olympic lifts). Somewhat differently, Bachele and Earle (2012) divide the exercises into exercises for the chest, back, shoulders, upper arms, legs, "core," and the whole body. In bodybuilding, Evans (2015) divides exercises according to muscle groups into exercises for shoulders, chest, back, arms, legs, and abdominal muscles and further divide them for individual muscle parts. For example, shoulder exercises are classified concerning different parts of the shoulder muscles (front, middle, back), where each part is responsible for moving the arm in different directions. Exercises for the neck muscles are not described in the above sections.

In addition to the above divisions, other authors have classified body weight exercises to improve strength and power. Harrison (2010) classifies strength body weight exercises into exercises for the upper body part, the lower body part, and the whole body. A more detailed classification of body weight exercises is performed by Contreras (2014), where a division of exercises is according to the following muscle groups: arms, neck and shoulders, chest, "core," back, thighs, buttocks, calves, and the whole body.

The Evans (2015) exercise classification clearly states which parts of the muscles are engaged when performing the exercises (e.g., the middle part of the shoulder during lateral dumbbell lifting). That consistency does not exist in the classification of Contreras (2014). This inconsistency may be that some body weight exercises involve several muscles simultaneously. It is impossible to completely isolate some muscle groups, unlike bodybuilding exercises when using weights and machines. In this regard, in single-joint movements, for example, the flexion in the elbow joint is not performed only by m. biceps brachii, but also other muscles that have the same function in that joint (m. brachialis, m. brachioradialis), as well as muscles that help the flexion movement (m. pronator teres, m. extensor carpi radialis longus muscle, m. flexor carpi ulnaris, and m. flexor carpi radialis) (Hochschild, 2016). Also, when performing a particular movement or exercise, several muscles are usually responsible, which can have different roles (agonistic, antagonistic, synergistic, etc.)

Mentioned indicates the importance of the body weight exercise classification. There are different criteria for classifying body weight exercises; the most important are the topological criterion, exercise complexity, muscle length, type of kinetic chain, the number of extremities involved in the movement, the anatomical plane. The analysis of different classification criteria requires knowledge of anatomy, biomechanics, physiology, strength training science, and other related disciplines.

With the increased popularity, there is also an increase in the number of body weight exercises. To reject doubt what body part and muscle is engaged during body weight exercise, it is necessary to perform an analytical classification of body weight exercises according to the topological criterion. Knowledge about engaged body parts and muscle groups of basic body weight exercises must be explicit and complete to make an appropriate choice and exercise order in a training program. Classification of body weight exercises is necessary for a more detailed study of individual exercises or exercises with common features. The problem in this paper is how to classify body weight exercises according to the topological criterion? The subject of this paper is the topological criterion for classifying body weight exercises, which primarily includes knowledge from anatomy and the science of strength training. According to the topological criterion, the exercises are classified regarding the part of the body and musculature that are engaged during the performance of the exercises. The aim of this paper is to describe, analyze and classify the basic body weight exercises from the basic set according to the topological criterion. The purpose of this paper was to create a clear overview of body weight exercises as a basis for successful training planning and programming.

Materials and Methods

The classification method consists of the following steps: a review of information sources, the definition of the basic set of exercises, selection of criterion for exercise classification and type of exercise classification, as shown in Figure 1.

Figure 1 Method review

Review of information sources

The review of information sources consisted of professional and scientific literature in the field of sports and exercise. Google Scholar and Journal of Strength and Conditioning Research databases were searched. The search used the keywords: "body weight", "body weight training", "body weight exercises", "calisthenics", "calisthenics strength", and "calisthenic exercises". The review included 54 papers and papers corresponding to this paper's topic were selected and analyzed.

Defining a basic set of exercises

To define the basic set of body weight exercises, the upper, middle, and lower body parts are chosen. Exercises in the basic set include mainly eccentric and concentric muscle contraction for the upper and lower body parts and isometric contraction of exercises for the middle part of the body ("core"). Exercises with additional external load (such as free weights, machines, elastic bands) are excluded because they change body weight. Also, exercises that involve reversible muscle contraction are excluded. Overall, 68 body weight exercises are chosen.

Selection of criteria for the classification of exercises

The topological criterion is chosen for the classification of body weight exercises, which is very common in the available professional and scientific literature (Kukolj, 2006; Ranisavljev & Ilić, 2010; Harrison, 2010; Contreras, 2014; Bachele & Earle, 2012; Haff & Triplett, 2016).

Type of exercise classification

There are different types of classification, such as analytic, synthetic, and regular classification. In this paper, a descriptive analytical classification is applied. According to Bielik (2019), two conditions need to be met for analytical classification:

1. All items from the basic set must be classified according to their properties, and all items must be classified in at least one class. In other words, no item from the basic set must remain unclassified.
2. Each item must belong to a maximum of one class. However, one item from a set can have two classification properties, i.e., to be classified into two classes, which is known as a dichotomy.

It is essential to point out that in this paper, the term item means body weight exercise. Also, the property of exercise refers to the primary engaged part of the body or musculature in a particular body weight exercise.

Results

The classification of exercises

Full body

The full body is an entity that is topologically divided into three parts: upper, middle, and lower body. The upper, middle and lower body parts represent classes I, II, and III. Further, the upper, middle, and lower body are divided into subclasses I and II levels. Concerning the active part of the body and the primarily engaged muscle (property of exercises) in performing body weight exercises, body weight exercises from the basic set are classified into appropriate classes and subclasses.

Upper body part - class I

The upper body (class I) can be divided into the following parts: neck, shoulders, chest, back, and upper arms, which form subclass I levels. Then, each part can be further divided within the subclass of level II. Thus the neck is divided into front, back, and side; shoulders: front, middle, and back; chest: upper, middle, and lower part; back: upper and lower part and upper arms: front and back part. Body weight exercises for class I, subclasses I and II levels are shown in Table 1.

Table 1 Classification of the upper body exercises - class I

Upper body	Neck	Front part	flexion		
		Side part	side flexion, rotation		
		Back part	extension		
	Shoulders	Front part	handstand push-ups, pike push-ups		
		Middle part	side plank rotation		
		Back part	inverted row to head		
	Back	Upper part	pull-ups, one arm pull up, inverted row, front lever row	backward trunk rotation, scapula elevation – depression, scapula protraction – retraction, shoulder shrugs on parallel bars	muscle-up
		Lower part			
	Chest	Upper part	push-ups with elevated feet		
		Middle part	push-ups, one arm push-up, planche push-ups		
		Lower part	dips		
Upper arms	Front part	elbow flexion, one arm elbow flexion			
	Back part	elbow extension, one arm elbow extension			

Table 1 included 26 exercises, of which 4 are for the neck, 4 for the shoulders, 8 for the back, 5 for the chest and 4 for the upper arms. The muscle-up exercise predominantly engages the back and chest (two subclasses I levels), within which are m. latissimus dorsi and m. pectoralis major the most engaged.

Middle body part - class II

The middle part of the body - "core" can be divided into the following parts: abdomen and back, which make up subclass I levels. Further, both subclasses level I may be divided into subclasses level II. The abdomen is divided into anterior and lateral (subclass II). Then, although the backs are already listed in the upper part of the body, they are included when performing "core" exercises, primarily their lower part (subclass II). Body weight exercises for class I, subclasses I and II levels are shown in Table 2.

Table 2 Classification of the middle body exercises - class II

Movement type	Middle body part - trunk or "core"			
	Abdomen			Back
	Front part	Side part		Lower part
Flexion	trunk flexion, hip flexion, V-up			
Anti-flexion	front plank, one arm front plank, "hollow body" hold, "dragon flag," "dead bug," "mountain climbers"			
Lateral flexion		side trunk flexion, side V-up		
Anti-lateral flexion		side plank, side "hollow body" hold		
Rotation			trunk rotation, cross V-up, standing golfer rotation	
Anti-rotation			cross mountain climbers	
Extension				trunk extension, "super-man"
Anti-extension				inverted plank, one leg inverted plank, "bird dog"

Table 2 included a total of 22 exercises, of which 9 (flexion: 3, anti-flexion: 6) for the abdomen – front part, 10 (lateral flexion: 2, anti-lateral flexion: 2; rotation: 3, anti-rotation: 1) for the abdomen - lateral part and 6 (extension: 2, anti-extension: 3) for the back - lower part.

Lower body part- class III

The lower part of the body can be divided into the following parts: the gluteus, thighs, and lower legs, which form subclass I levels. These parts are further divided into subclass II level, so the gluteus is divided into the back and side part, thighs into the front and back part, lower legs on the front and back part. Body weight exercises for class I, subclasses I and II levels are shown in Table 3.

Table 3 Classification of the lower body exercises - class III

Number of extremities involved	Lower body part					
	Gluteus		Thighs		Lower leg	
	Back part	Side part	Front part	Back part	Front part	Back part
two	glute bridge		squat, knee extension	Nordic curl, knee curl, hinge	dorsiflexion	standing calf raise, squat calf raise
one	one leg glute bridge, clamshell	hip abduction	lunge, Bulgarian squat, one leg squat	one leg knee curl, one leg hinge	one foot dorsiflexion	one leg calf raise, one leg squat calf raise

Table 3 included a total of 20 body weight exercises. The gluteus has 4 exercises for the back part, of which 1 engages both extremities and 2 exercises one extremity and 1 exercise for the side part, which engages one extremity. A total of 10 exercises are included for the thighs, of which 2 are exercises for the front part that engage both extremities and 3 exercises that involve one extremity; 3 exercises for the back part that engage both extremities and 2 exercises that engage one limb.

Then, the lower legs include 6 exercises for the front part, of which 1 engages both extremities, 1 one extremity and 2 exercises for the back part that engages both and/or one extremity.

Discussion

Various 68 exercises for the upper, middle, and lower part of the body were analyzed, shown in tables 1, 2, and 3. Exercises include eccentric and concentric but also isometric contraction for the core muscles. Also, exercises that can be performed with one or both engaged limbs were analyzed. When classifying exercises for the middle part of the body, the movement type was also considered. Also, only exercises that can be performed with minimal equipment, such as a horizontal bar and parallel bars, are being included.

All 68 body weight exercises using the topological criterion were classified regarding the primarily engaged muscle and body part. For upper body 26, middle 22, and lower 20 body weight exercises. In the upper body, exercises: pull-ups, one arm pull-ups, inverted row, one arm inverted row, front lever row engage primarily *m. latissimus dorsi* (Delavier, 2005; Contreras, 2014; Evans, 2015; Low, 2016). For these reasons, these exercises are considered dichotomous. Due to the difficulty of exercises of the planche and front lever, for most exercisers and athletes, it is suggested to perform variations, i.e., progression exercises of the planche and front lever, which can be performed in the tucked position of the trunk (tuck planche; tuck front lever) and semi-tucked (advanced tuck planche and front lever) position with bent legs at the hips. In the middle body part, exercises: trunk extension, inverted plank, inverted plank on one leg, bird dog engage and strengthen above all *m. erector spinae* (Graham, 2009; Ko & Song, 2018).

Harrison's classification (2010) includes mountain climbing and side climbing exercises, which predominantly engage the "core," which in this paper is a property (primary muscle engagement) of exercises for classification according to the topological criterion. Therefore, it is not justified to classify these exercises in the whole body class but preferably in the "core" subclass. In addition to Harrison's (2010) classification of body weight exercises, this classification involves planche and front lever exercises. Those exercises can serve for further improvement in strength, power, and muscle hypertrophy. Next, the middle body classification showed that movement type and body part determined exercises. It should be noted that anti-movement type exercises involve the whole abdomen and back part (e.g., front plank, side plank, and inverted plank). That is not always the case with part-oriented exercises, such as trunk flexion, side trunk flexion, and back extension. Also, the muscle *erector spinae* is a muscle that extends in the body's upper and middle parts. So, exercises trunk extension, inverted plank, inverted plank on one leg, bird dog are considered dichotomous. Lower body exercises can be executed with one or two extremities and most exercises are classified for thighs (front and back part).

Previous body weight literature has exciting findings. For example, the body weight push-up and squat with two extremities can be used to screen an athlete's movement competency and capability (Kritz et al., 2009; Kritz et al., 2010). Proper performance of exercise helps prevent injuries when an additional load, such as weights, is incorporated. Also, it enables a better training stimulus and an organism's adaptation to training demands. Some novel literature suggests that body weight exercises improve strength and power among different populations. Kotarsky (2018) found that push-up variation can be similarly effective for improving upper body pushing strength as bench press exercise in moderately trained males.

This finding sets an open question. Can other body weight exercise variations and progressions lead to similar effects in different populations and body parts? Next, Guerra and colleagues (2019) found that body weight exercises, such as squats, lunges, push-ups, dips, plank, horizontal and vertical jumps, can improve strength and power for school children age 15 to 16 years. They found a statistically significant difference ($p = 0.001$; $p = 0.019$, respectively) for push-ups and curl-ups among training and control groups. Also, medicine ball throw improved but without statistically significant difference ($p = 0.532$) among groups. Professors of physical education must be encouraged to implement this and other body weight exercises to improve children's motor abilities safely and continuously.

The general population can benefit from body weight exercises also. Thomas and colleagues (2017) found that exercises, such as "hollow body," planche lean, squats, lunges, wall handstand holds, inverted row, tuck front pull can improve body posture in untrained individuals. This finding is essential for everybody who wants to improve their health in a low cost and accessible manner. Recently, Klisarić (2020) found no statistically significant difference ($p < 0.05$) in morphologic characteristics among calisthenic exercisers and track athletes. That implies that body weight exercise can improve body composition and quality of life, which is vital for the general population. Also, Cigerci and Genc (2020) found statistically significant difference ($p = 0.000$; $p = 0.012$) for fat percentage (%), and fat-free mass, among exercise and control group. The program was applied for 3 days a week for 8 weeks and included exercises such as V-up, "Superman," "Dragon Flag," plank, pike push-up, mountain climber, and others, which reduced body fat percentage and increased fat-free mass in soccer players.

Analyzed and classified body weight exercises present a clear overview which can serve as an initial point in training planning and programming. Classified body weight exercises enable a straightforward and easy way to choose which body parts and muscles to train and improve motor abilities. It should be noted in mind that this paper does not cover all body weight exercises but basic exercises, which mainly involve performing movements in one plane. There are no exercises in which performance requires more movements in different planes, such as lunge with trunk rotation, glute bridge with hip abduction, squat with hip abduction. Also, exercises that involve reversible muscle contraction are not included.

Conclusions

All body weight exercises from the basic set are classified according to the topological criterion regarding the exercise's primarily engaged muscles and body parts. Most exercises are for the upper body, then the middle body, and the lower body part. More precisely, 26 upper body, 22 middle body, and 20 lower body part exercises are analyzed and classified. Type of the movement and number of extremities involved are also considered. Furthermore, analysis of body weight exercises revealed dichotomy, which exists in two cases. The first case occurs when the muscle is primarily engaged in performing the exercise is topologically represented in both classes (upper and middle part of the body). The second case occurs when the exercise is complex, i.e., when it is performed as one movement but requires two subclasses' primary engagement (back and chest). When analyzing and classifying body weight exercises, the dichotomy must be concerned.

The presented descriptive analytical classification of body weight exercises according to the topological criterion can serve as a basis for planning and programming training of different needs and goals. This knowledge rejects doubt about which body parts and muscles are engaged in performing body weight exercises. It is possible to choose and arrange body weight exercises with a certainty of which body parts and muscles are engaged.

Analyzed exercises require minimal equipment and props, making them widely available, easily accessible, and applicable in almost all training conditions. Strength and conditioning coaches, fitness professionals, physical education professors, and other experts can use classified body weight exercises to ensure which body parts and muscles are engaged during exercise performance. For future research, different body weight exercises and their variations can be analyzed and classified using descriptive analytical classification.

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