

Applying Biomechanics in Physical Education

Physical educators teach a wide variety of human movements, and biomechanics provides a rationale critical for evaluating technique and prescribing intervention to help young people improve. Biomechanics also allows physical educators to identify exercises and physical activities that contribute to the physical development of various muscle groups and fitness components. This chapter illustrates how biomechanical knowledge and the nine principles of biomechanics can be integrated with other sport sciences in qualitative analysis of human movement. Five skills commonly taught in physical education are discussed, and the various tasks of qualitative analysis (Knudson & Morrison, 2002) are emphasized in the examples. Real movement performances and typical teaching cues are used to show how biomechanics is applied to real-world physical education. Qualitative analysis is a critical evaluative and diagnostic skill that can be employed for improvement of movement in physical education.

QUALITATIVE ANALYSIS OF KICKING TECHNIQUE

The primary task of a professional physical educator may be the qualitative analysis of movement technique to facilitate learning of motor skills. Biomechanics is the primary sport science focusing on movement technique, so it is logical that physical educators should use the principles of biome-

chanics in helping students move safely and effectively. Biomechanics provides knowledge relevant to all four tasks of qualitative analysis (Figure 2.9).

Imagine that you are an elementary physical educator planning a lesson on kicking as a lead-up to soccer, so you are involved in the preparatory task of qualitative analysis. In preparing to teach and qualitatively analyze kicking, you list the critical features and teaching points of the movement (Table 9.1). As students practice this skill, you are planning to evaluate these critical features and diagnose student performance using biomechanical principles. Which biomechanical principles seem most relevant to the critical features of high-speed place-kicking?

Five of the critical features presented in Table 9.1 are strongly related to several of the biomechanical principles. The opposition and coordination involved in high-

Table 9.1
CRITICAL FEATURES AND TEACHING CUES
FOR FAST PLACE KICKING

Critical feature	Possible teaching /intervention cues
Visual focus	Head down and focus on the ball
Opposition	Turn your hip to the ball
Foot plant	Plant your foot next to the ball
Coordination	Swing your hip and leg
Impact position	Kick the center of the ball
Follow-through	Follow-through toward the target

speed kicking are all strongly influenced by the principles of range of motion, coordination, and segmental interaction. In addition, the force–motion, force–time, and optimal projection principles are important in kicking as well. The teacher might plan to keep the principles of inertia, spin, and balance in the back of their mind, so they will not be a focus of observation. These three principles are not likely to play a significant role in the kicking executed by most primary school children.

A child making a full-effort kick toward a goal is observed to consistently have a technique like that illustrated in Figure 9.1. Remember that good qualitative analysis requires the analyst to observe several performances so that clear trends of strengths and weaknesses can be identified, rather than jumping to conclusions or identifying unimportant “errors” (Knudson & Morrison, 2002). What critical features are strongly and weakly performed? These

judgments are part of the evaluation process within the evaluation/diagnosis task of qualitative analysis.

The child illustrated in Figure 9.1 is clearly at a low developmental level of kicking. The teacher could praise the student's focus on the ball, strong approach, and balance during the kick. The list of biomechanical weaknesses is long at this beginning stage of learning. The biomechanical principles that are weakly incorporated into the kick are force–motion, optimal projection, inertia, range of motion, coordination, and segmental interaction. The student applies a suboptimal force to the ball because they plant the support foot well behind the ball, and impact the ball with their toe rather than the proximal instep (top of the shoelaces). Low-trajectory shots are desirable, but this kick, rolling along the ground, will slow the ball down as it rolls, making it easier for opponents to intercept. Finally, the student needs considerable

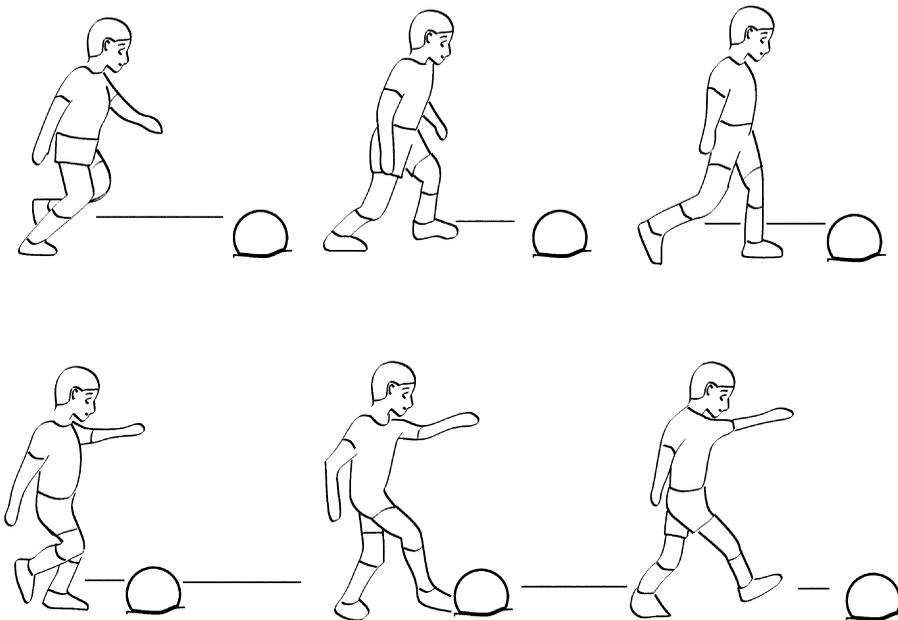


Figure 9.1. The technique of a young person making a high-speed soccer kick. The time between images is 0.08 s.

practice to increase the range of motion of the kick and to refine a well-timed sequential coordination that transfers energy through segmental interactions. Highly skilled kickers will approach the ball at an angle to increase the contralateral hip range of motion that can be sequentially combined with the hip and knee motions of the kicking leg. Which of these weaknesses do you think is most important to kicking success? One effective intervention strategy would be to provide a cue to plant their foot next to the ball. This is a simple correction that might be related to other weaknesses and might motivate the student with initial success and improvement.

Toward the end of the lesson you notice another child consistently kicking as in the sequence illustrated in Figure 9.2. What biomechanical principles are strongly or weakly performed in Figure 9.2?

The student depicted in Figure 9.2 is more skilled than the student from the pre-

vious example. Note the more vigorous approach to the ball. The intensity (inertia) of this approach is apparent in the length of the hurdle to the plant leg and the trunk lean used to maintain balance. It is hard to judge from the figure, but the ball is kicked at the desirable low trajectory. Some educators might conclude that all the biomechanical principles were well applied in this kick. The only two principles that might be slightly improved are range of motion and coordination. If the student were to approach the ball from a more oblique angle, the rotation of the pelvis on the left hip could be increased (range of motion) and combined (sequential coordination) with the good coordination of the kicking hip and knee.

Which of these small improvements, range of motion or coordination, do you think could be easily changed by this student in practice? Improvement in what principle would increase performance the

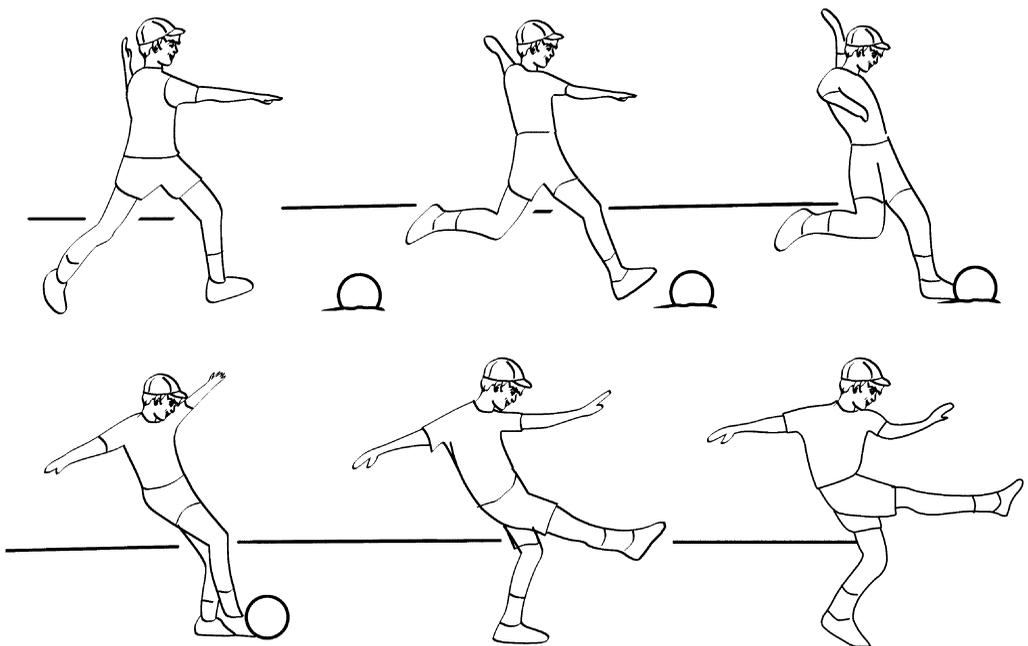


Figure 9.2. The technique of another soccer player kicking for maximum speed. Time between images is 0.08 s.

most? These are the issues that are important for a physical educator to examine in the diagnosis and intervention stages of qualitative analysis. The teacher might review some recent research and review papers on kicking (Barfield, 1998; Davids, Lees, & Burwitz, 2000; Dorge, Bull Andersen, Sorensen, & Simonsen, 2002). The following examples of qualitative analysis will illustrate the use of the biomechanical principles in these more difficult phases of qualitative analysis.

QUALITATIVE ANALYSIS OF BATTING

Imagine you are a physical educator working on batting with young boys and girls. Most primary school children receive some experience intercepting and striking objects from elementary physical education. The difficulty of the skill dramatically increases when these young people move from batting slow-moving or stationary (batting tee) objects, to balls thrown with greater speed and spin. Use the technique points and cues in Table 9.2 to analyze the batting technique of the student illustrated in Figure 9.3. Assume the technique illustrated is representative of most batting attempts off a batting tee by this child. What biomechanical

principles seem to be well applied by this child, and what principles are poorly applied? More importantly, prioritize the weaknesses in an order that you think would result in the best batting performance if the weaknesses were improved.

Most all of the biomechanical principles are relevant to batting performance. The student in Figure 9.3 strongly incorporates many biomechanical principles into batting. His strengths include balance, inertia, and coordination. He strides into the swing and gets the bat in line with the ball. The force–motion principle could be improved since the bat does not squarely collide with the ball (note the tipping batting tee). The principles of force–time and range of motion may be the major weaknesses that could be improved. The student exaggerates the stride and uses an abbreviated follow-through. The physical educator must diagnose the situation and decide if instruction should be focused on the larger than normal range of motion and time in the stride or on the less than expected time/range of motion in the follow-through. Weighing the importance of these principles so as to lead to potential improvement is very difficult. Remember, we noted that this student would soon be applying this skill in the more dynamic condition of impacting a moving ball.

Since the student has good balance, their long stride (which increases range of motion and time of force application) could generate more speed without adversely affecting accuracy. This is typical for a young person with limited upper body strength trying to clobber a ball off a batting tee. Maintaining a long (time and distance) stride in hitting pitched balls, however, is generally a bad tradeoff. Accuracy in contacting the ball becomes more important in dynamic hitting conditions.

It may even be possible to maintain a similar bat speed with a shorter stride if the student improves his follow-through. An

Table 9.2
CRITICAL FEATURES AND TEACHING
CUES FOR BATTING

Critical feature	Possible teaching/ intervention cues
Visual focus	Head down and focus on the ball
Opposition	Sideward stance
Readiness	Bat up and elbow back
Weight shift	Short stride toward the pitch
Coordination	Throw your hands through the ball
Follow-through	Follow-through around your body

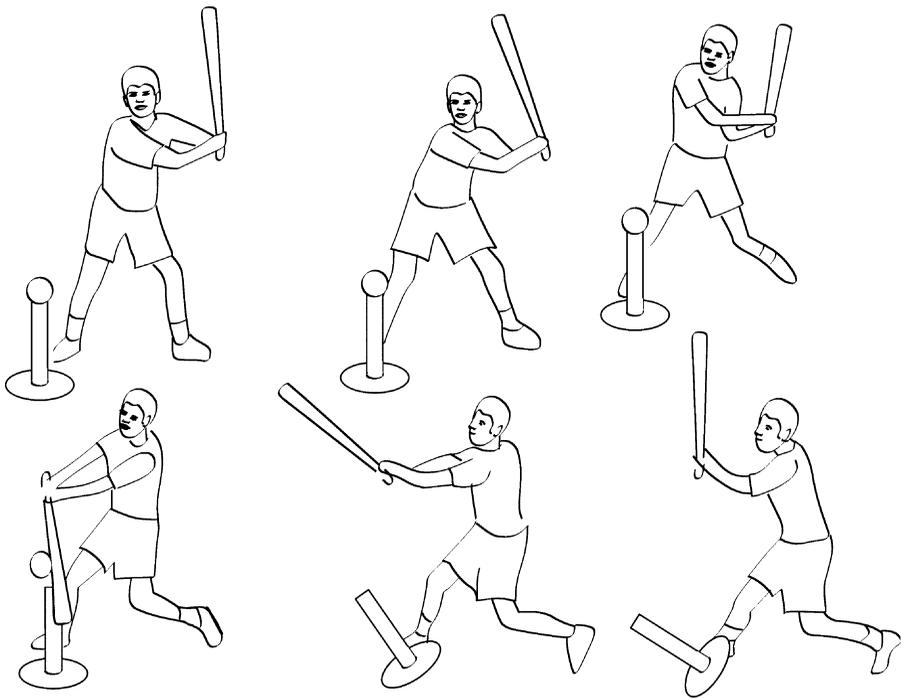


Figure 9.3. A physical education student batting a ball from a tee. Time between images is 0.1 seconds.

abbreviated follow-through means that the hitter is slowing down the bat before impact. Skilled striking involves generating peak velocity at impact, delaying negative accelerations until that point (Knudson & Bahamonde, 2001). The force–time and range-of-motion principles also imply that a short follow-through may increase the risk of injury since the peak forces slowing the movement must be larger. Since the follow-through is an important strategy for minimizing the risk of injury in many movements, the physical educator should rate this intervention ahead of adjusting the preparatory (stride) range of motion. Once the student gets comfortable swinging through the ball, they may have more bat speed at impact, and might be more willing to reduce their stride and weight shift when hitting pitched balls. More recent research on baseball batting has focused on differ-

ences in various bats (Greenwald, Penna, & Crisco, 2001) and hitting from both sides of the plate (McLean and Reeder, 2000). The next section provides an example of diagnosis using biomechanical principles in basketball shooting.

QUALITATIVE ANALYSIS OF THE BASKETBALL FREE THROW

The previous qualitative analysis examples involved movements that must be matched to unpredictable environmental conditions. Motor learning classifies these movements as *open skills*, while skills with very stable conditions are called *closed skills*. When physical educators teach and analyze closed motor skills, they can be confident that performance is more strongly dependent on stereotypical technique rather than a

variety of effective techniques. The standardized conditions of the free throw in basketball mean that the stereotypical techniques of a set shot would be optimal. Table 9.3 lists the key technique points and intervention cues that describe good free throw shooting technique.

Suppose an elementary school student is working on her free throw using modified equipment. Using a smaller ball and lower basket is critical to teaching good shooting technique with young children. At this age, they typically cannot employ good shooting technique using a regular ball and a 10-foot-high basket because of their lack of strength. Suppose that observations of the free throw attempts of a young child shows technique consistent with that illustrated in Figure 9.4. Identify the biomechanical principles that are strengths and weaknesses. Then diagnose the situation to determine what biomechanical principle should be the focus of any intervention.

The principles she can be complimented on are her good balance, simultaneous coordination, and spin on the ball. It is difficult to see in Figure 9.4, but this child used only one hand and one leg to shoot because she stepped into the shot. Weaknesses in her shooting technique are the limited use of range of motion and the force–time principles since she is not easily generating the ball speed needed for the shot. Another weakness is in the principle of optimal trajectory. Biomechanical research on shooting has shown that the optimal angles of projection for most set and jump shots are between 49 and 55° above the horizontal (Knudson, 1993). Young basketball players often select “flat” shooting trajectories, which actually require greater ball speed and often have angles of entry that do not allow the ball to pass cleanly through the hoop. This weighing of potential benefits of working on range of motion or initial shot trajectory is the essential diagnostic deci-

Table 9.3
CRITICAL FEATURES AND TEACHING
CUES FOR THE FREE THROW

Critical feature	Possible teaching/intervention cues
Staggered stance	Shooting side foot forward
Shooting plane	Align your arm with the basket
Height of release	Release high above your head
Coordination	Extend your whole body
Angle of release	Shoot with high arc
Ball rotation	Flip your wrist

sion in this case. There are several biomechanical reasons why it is likely more beneficial to work on shot trajectory than increasing range of motion. First, using the desirable trajectory increases the angle of entry and the probability of a made shot. Second, this slightly higher trajectory requires less ball speed than a very flat one. Third, the young player is likely to increase her strength while the desirable trajectory will remain the same. The interaction of biomechanics and performer characteristics suggests to the teacher that subsequent practice should focus on a slightly higher shot trajectory.

EXERCISE/ACTIVITY PRESCRIPTION

Another important content area of physical education is fitness. Physical educators planning to increase student physical fitness must employ biomechanical knowledge to determine the most effective exercises for various parts of the body and fitness components. Like strength and conditioning professionals, physical educators qualitatively analyze exercise technique to be sure that students are safely training their bodies.

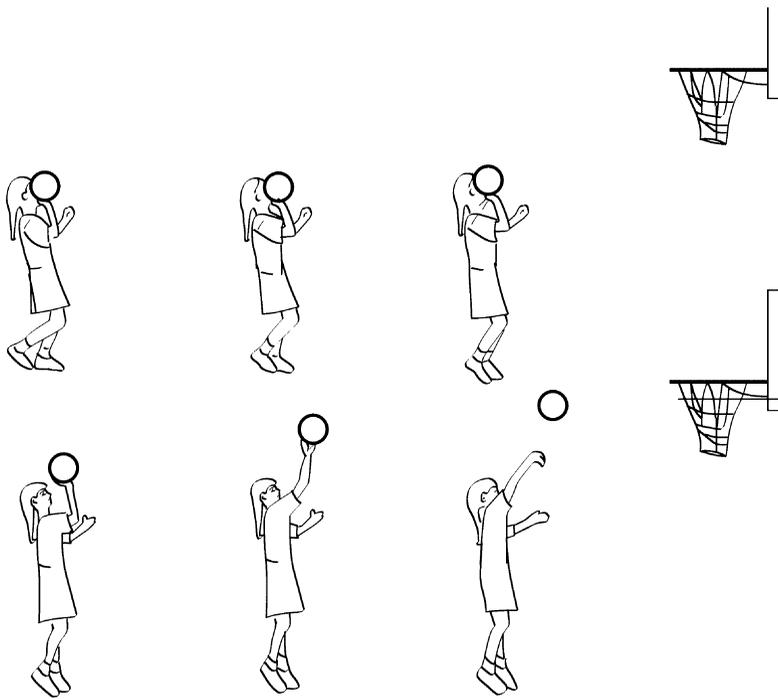


Figure 9.4. An elementary student shooting a free throw at an 8-foot-high hoop. Time between images is 0.07 s.

During the first week of your high school weight-training unit, you notice many students performing their curl-up exercises like the student depicted in Figure 9.5. You want to immediately provide some group feedback to help many students with this exercise technique and reinforce some of the technique points you made earlier. Make a list of the critical features or technique points that are important in the curl-up exercise. What biomechanical principles are most related to the objectives of doing curl-ups for health-related fitness (muscular endurance)? Which of the biomechanical principle(s) seem to be weakly applied in the concentric phase of the curl-up for the student shown in Figure 9.5?

The purpose of curl-up exercises is to focus a conditioning stimulus on the abdominal muscles by limiting the contribution of hip flexors and other muscles. The

biomechanical principles that are important in this objective are Force–Motion, Range of Motion, Inertia, and Force–Time. The inertia of the body provides the resistance for the exercise, and the range of motion for the exercise should focus the stress (force–motion) on the abdominal muscles. The repetitions should be slow and controlled (Force–Time) for safety and to promote training for muscular endurance.

The student in Figure 9.5 has several weaknesses in his curl-up technique. He uses too much range of motion, performing more of a sit-up (hip flexion) than a trunk curl. In a curl-up exercise, the abdominal muscles should raise the shoulders to about a 30 to 40° angle with the hip (Knudson, 1996), just lifting the shoulder blades off the ground. Hip flexion is required if the shoulders are to be raised further. The student also decreases the resistance or inertia by

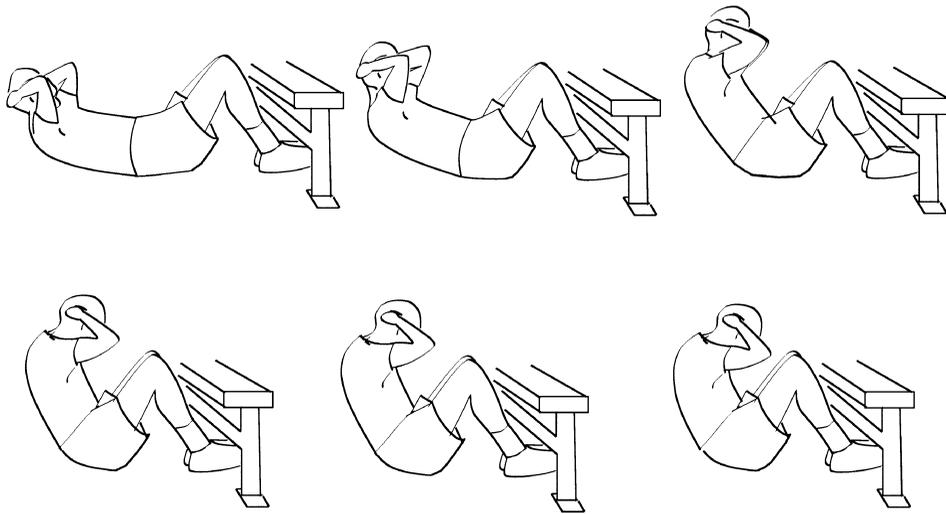


Figure 9.5. Concentric phase technique of a curl-up for a high school student. Time between images is 0.17 s.

keeping the weight of the arms close to the transverse axis of rotation for trunk flexion. The third weakness is in stabilizing his feet with the weight bench. This affects both the Force–Motion Principle and the Principle of Inertia. By stabilizing the feet with the bench, the performer has essentially unlimited inertia for the lower extremities. This allows hip flexor activation to contribute to trunk flexion through the kinematic chain of the lower extremity, so the Force–Motion Principle is not applied well for the training objective of isolating the abdominal muscles. Performing the curl-up without foot stabilization would require greater abdominal activation and stabilization to lift the trunk without hip flexors. The time information in the caption for Figure 9.5 suggests that the student was applying the Force–Time Principle well; in other words, he did not perform the exercise too fast.

The best intervention in this situation is to provide group intervention, reminding all students to perform curl-ups without lower-extremity stabilization. This exercise may feel more difficult, but the teacher can use this opportunity to reinforce the idea

that the students are *training* and *teaching* their abdominal muscles an important trunk-stabilizing task. Focusing on using more abdominal muscles for a longer time (Force–Time Principle) better simulates the nearly isometric actions of the muscles in stabilizing the trunk and pelvis. There is a large body of physical therapy literature focused on training specific abdominal muscles so as to stabilize the trunk (McGill, 1998; Vezina & Hubley-Kozey, 2000). The teacher could then provide some individualized intervention for the student. One good strategy would be to compliment (reinforce) the good exercise cadence, but challenge the student to place his hands on top of his head and keep the arms back to increase the resistance for the exercise.

QUALITATIVE ANALYSIS OF CATCHING

Imagine that you are a junior high school physical educator teaching a basketball unit. You have been ingenious in getting the students to realize the rewards of moving

without the ball and passing rather than dribbling. There is one small problem that many of the students have poor catching skills. You previously taught students the critical features of catching (Table 9.4) using a variety of cues. In watching a passing drill, you notice a student receiving passes similar to what is illustrated in Figure 9.6. What biomechanical principles are well or poorly incorporated in catching the basketball? Diagnose the situation and prioritize the importance of the biomechanical principles in successful catching for this player and think about what the best intervention would be.

The player has good balance and uses simultaneous coordination in receiving the ball. The Force–Motion Principle was well applied by predicting the location of the ball, intercepting the ball with the hands, and applying the force through the center of gravity of the ball. The two principles

Table 9.4
CRITICAL FEATURES AND TEACHING CUES
FOR TWO-HANDED CATCHING

Critical feature	Possible teaching/ intervention cues
Readiness	Athletic stance
Visual focus	Watch the ball
Intercept	Move and reach towards the ball
Hand position	Thumbs in or thumbs out
Absorption	Give with your hands and arms

that could be improved are Range of Motion and Force–Time. Since you are a good physical educator, you also note the non-biomechanical factors relevant in this situation: the player appears to visually focus on the ball, is motivated, and is trying her best.

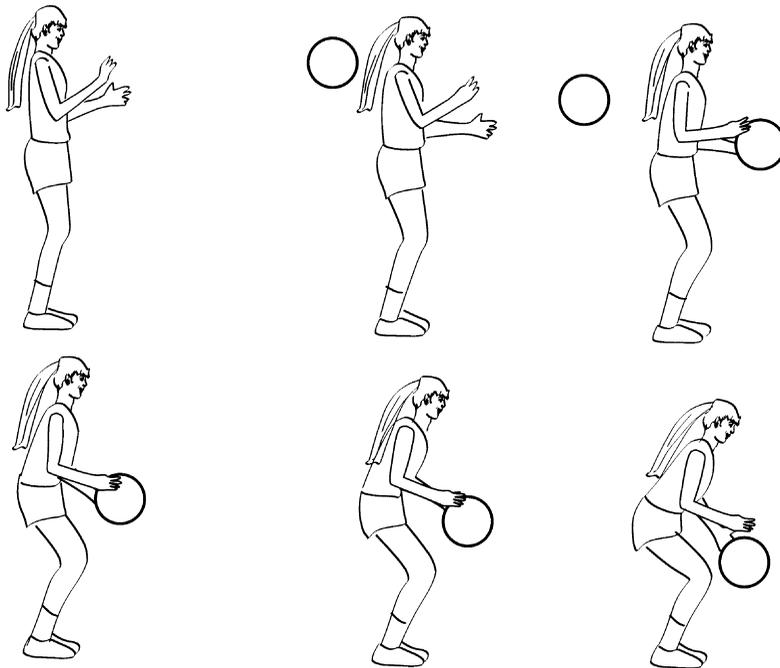


Figure 9.6. A junior high school basketball player catching a pass. Time between images is 0.1 seconds.

Diagnosis of this situation is not as difficult as many qualitative analyses because the two weaknesses demonstrated in this example are closely related. Increasing the range of motion in receiving the ball will generally increase the time of force application. You must decide if the player's catching and basketball performance would improve most if her attention were focused on reaching more to intercept the ball or emphasizing how the arms bring the ball in. Both biomechanical principles are important. Can you really say one is more important than the other? The player would clearly improve if she stepped and reached more to intercept the ball earlier and provide more body range of motion to slow the ball down. Increasing range of motion also has a secondary benefit by reducing the risk of a pass being intercepted. How the hand forces opposing ball motion, however, has the most influence on whether a ball is caught or bounces out of a player's grasp. This is a case where some professionals might disagree on the most appropriate intervention. In class, you only have a few seconds and you provide a cue to a student to focus on "giving" with her hands and arms as she receives the ball. You say, "See if you can give with your hands and arms as you catch the ball. Bring that ball in so you barely hear a sound."

SUMMARY

The principles of biomechanics provide a method for physical educators to qualitatively analyze human movement. Several sport and exercise situations commonly faced by physical educators were discussed. The physical educators in the examples employed cue words or phrases to communicate the essence of the biomechanical principles to their students. Physical educators should also integrate the biomechanical principles with their experience,

as well as knowledge from other subdisciplines of kinesiology to provide an interdisciplinary approach to qualitative analysis (Knudson & Morrison, 2002).

DISCUSSION QUESTIONS

1. What biomechanical principles are more important in kicking versus trapping a soccer ball?

2. What are the typical teaching points or cues for baseball/softball batting? What biomechanical principles are relevant in these teaching points?

3. How is the application of biomechanical principles different in the free throw versus the jump shot?

4. Which biomechanical principles are relevant to the pushup exercise? How does changing hand position from a wide base of support to a narrow base of support modify the importance of these principles?

5. What biomechanical principles are most relevant to catching a softball? Catching a medicine ball?

6. What are typical teaching points in jumping to rebound a basketball? What points are most important based on the principles of biomechanics?

7. What biomechanical principles are important in throwing a pass in American football?

SUGGESTED READING

Adrian, M. J., & Cooper, J. M. (1995). *Biomechanics of human movement* (2nd ed.). Madison, WI: Brown & Benchmark.

Hay, J. G. (1993). *The biomechanics of sports techniques* (4th ed.). Englewood Cliffs, NJ: Prentice-Hall.

Knudson, D. (1991). The tennis topspin forehand drive: Technique changes and critical elements. *Strategies*, 5(1), 19–22.

Knudson, D. (1993). Biomechanics of the basketball jump shot: Six key teaching points. *JOPERD*, 64(2), 67–73.

Knudson, D., & Morrison, C. (1996). An integrated qualitative analysis of overarm throwing. *JOPERD*, 67(6), 31–36.

Knudson, D., & Morrison, C. (2002). *Qualitative analysis of human movement* (2nd ed.). Champaign, IL: Human Kinetics.

WEB LINKS

AAHPERD—American Alliance for Health, Physical Education, Recreation, and Dance is the first professional HPERD organization in the United States. The National Association for Sport and Physical Education (NASPE) should be selected from the list of associations on this site.

<http://www.aahperd.org/>

Coaching Information Service.

<http://coachesinfo.com/>

PE Links 4U—website for sharing physical education teaching ideas.

<http://www.pelinks4u.org/>

PE Central—website for sharing physical education teaching ideas.

<http://www.pecentral.com/>