

GRADE 11 PHYSICAL EDUCATION & HEALTH

First edition

5 units

10 lessons · one quarter

A video for every lesson

FIRST EDITION

COURSE GUIDE

This short course follows the same five strands as every School Launch PE year (keeping active, water, food, strength and the heart and lungs) at a high-school level. Eleventh grade asks the questions a serious young athlete asks. How do exercise and sleep feed each other, and what does the evidence say about mood? How do you protect your knees and ankles? Why must the first two weeks of hot-weather practice be gradual, and how can a runner drink too much? When should you eat around training, and how do you feed a family well on a budget? How is power trained safely, and how do you build strength for your own sport? What are lactate threshold and VO₂ max, and how do you plan a race? Each lesson is built around a real person or study: Nathaniel Kleitman's cave experiment, the 11+ trial in Norway, Korey Stringer, the 2002 Boston Marathon study, Bergström and Hultman's one-legged cycling, Ellen Swallow Richards, Yuri Verkhoshansky and Ray Ewry, Boyd Epley, Karlman Wasserman's threshold and Billy Mills.

Every lesson follows the same path: **the story**, then **how they figured it out**, then **how your body works**, with real physiology and worked numbers (sweat rates, grams of carbohydrate, unit prices, hang time and jump height, estimated strength, VO₂ max and race splits), and last **try it**: a real workout, test or kitchen task, recorded in a fitness journal and repeated to improve. Strength and power work follows the high-school safety rules: a knowledgeable adult present, a spotter for pressing lifts, technique first, low jump volume with safe landings, and no one-repetition maximum testing.

God made the body good and gave it to us to care for. This course is about stewardship, strength, joy in movement and good habits, never about size or looks; students are measured only against their own effort and improvement. The old saying *Fabricando fit faber*, "by making, one becomes a maker," fits training well: fitness is built by practice, a little more each week, with rest between. The quarter

ends with a family fitness day built around a 5K or shorter family race that the student plans and leads.

Videos come mostly from university, hospital and sports-medicine sources: Duke Health, a university sports-medicine surgeon, the Hospital for Special Surgery, Arkansas Children's, McMaster University, the Korey Stringer Institute at the University of Connecticut, PBS Digital Studios' Two Cents, a university exercise physiologist and the Olympics' official channel, with a few lectures made for coaches and medical students. These older videos are meant for adults and teenagers, so a parent should watch along; the lesson notes say where to stop and what to skip. Every video was previewed for accuracy and for modest dress. Some channels end with an invitation to subscribe or advertise a course for coaches; you can stop the video when the teaching ends.

Start with Lesson 1.1 →

WHO IT IS FOR

Written for students in grade 11 (about ages 16–17) who read independently, are comfortable with algebra and simple formulas, and can keep careful records. A parent or other knowledgeable adult supervises every activity, is present for all free-weight and jumping work, and helps in the kitchen. Nothing needs to be bought: every activity works with household things such as a towel, a sturdy step, a wall, a backpack with books, water jugs, a broom handle, a bathroom scale, measuring cups and a timer. Light dumbbells or a kettlebell are optional in Unit 4.

HOW TO USE THIS COURSE

1. **The weekly rhythm.** The quarter has 10 lessons, one a week, each with three sessions of 45–50 minutes. Session 1 is the warm-up, the video, the teaching and the picture study, with a little movement. Session 2 is the activity (the workout, test or kitchen task) and the fitness journal. Session 3 repeats the activity and tries to improve on it. In the second week of each unit, use part of Session 3 for the unit review and the unit challenge. On other days, aim for at least 60 minutes of moderate to vigorous activity, with muscle- and bone-strengthening activity on at least 3 days a week, as the *Physical Activity Guidelines for Americans* recommend for ages 6–17.

2. **Check with your doctor first.** A parent should know about and supervise every activity. If the student has asthma, a heart condition, diabetes, a recent injury or any other health concern, check with the doctor before starting, and follow the doctor's advice about what to change. A student on a school team should also follow the coach's and athletic trainer's plan.
3. **Story, then science, then doing.** The core ideas can be read alone, but they are better discussed together. Ask the student to explain each paragraph back, to name what was measured in each study, and to redo the worked numbers with his or her own data. High-school lessons use real terms (circadian rhythm, anterior cruciate ligament, plasma volume, hyponatremia, glycogen, stretch-shortening cycle, needs analysis, lactate threshold) and simple formulas.
4. **Picture study.** Each lesson has one public-domain painting or historic photograph chosen for what it shows about work, rest, food, water or movement. Look at it quietly for two minutes, put it away and tell everything you remember, then bring it back and work through the "look for" items and questions.
5. **The fitness journal.** Use one notebook for the quarter. Every activity is done, recorded and done again: hours of sleep, seconds of balance, heart rates, ounces of fluid, grams on a label, dollars per serving, inches jumped, reps and loads, splits. Date every page, add an effort rating from 1 to 10, and write how it felt and what you will change next time. Honest records matter more than big numbers.
6. **Health, not looks.** We talk about what bodies can do and how to care for them, never about size or shape. We never count or restrict calories or call foods bad; calories appear only as a unit of food energy (carbohydrate and protein about 4 per gram, fat about 9). Foods are "nutrient-dense" foods and "treat" foods, and feasts and treats are good gifts in their place. In Lesson 2.2 the student reads a bathroom scale before and after exercise to measure sweat loss; only the difference is written down, as fluid lost, never body weight. Students should not use supplements, protein powders or energy drinks; real food is enough. Grades come from effort, consistency and personal improvement.
7. **Optional books and gear.** Some units list free government, university or children's-hospital pages, or simple gear such as light dumbbells or a water bottle with ounce marks. They are never required.
8. **Unit review and unit challenge.** Each unit ends with a 100-point review (with worked calculations and short written answers) and a unit challenge: a two-week

sleep, activity and warm-up log; a personal hydration and heat plan; a week of planned and cooked meals with costs; a four-week power and strength plan; or a race plan and the family fitness day. Keep the challenge pages in a folder.

9. **Safety.** Read the safety note before each activity. Warm up first and cool down after. Stop and tell an adult right away at chest pain, dizziness, fainting, trouble breathing, confusion or sharp pain; tired muscles are normal, joint pain is not. Free weights are used only with a knowledgeable adult present and a spotter for any pressing lift, with technique learned first, and there is no maximum-lift testing: strength is estimated from a set of 8–10 good reps. Jump training uses low volume, soft landings and a good surface. In heat, train early or late, in shade, with water and a plan for emergencies. A parent supervises knives and the stove and checks for food allergies. Exercise and food are never used as a reward or a punishment.
10. **The family fitness day.** In the last week, the student plans and leads a family fitness day: a warm-up, a family 5K (or a shorter course for younger members, walking welcome), a water table, a recovery meal the student helps cook, and a short talk on what the student learned this quarter. Everyone moves at his or her own pace.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–2

Keeping Active

What the evidence says about exercise, mood and sleep, from Nathaniel Kleitman’s 1938 cave experiment to the 2018 *Physical Activity Guidelines*, with a sleep and activity log; and protecting the knees and ankles with the 11+ warm-up tested in Norway in 2008, with a landing and balance check.

1.1 Exercise, Mood and Sleep

1.2 Knee and Ankle Injury Prevention: The 11+

UNIT 2 • WEEKS 3–4

Hydration

Heat acclimatization in the first two weeks of hot-weather practice, the Korey Stringer story and “cool first, transport second”; and hydration for endurance events, from the 2002 Boston Marathon study of hyponatremia to a sweat-rate test and a drinking plan that avoids both too little and too much.

2.1 Heat Acclimatization: The First Two Weeks

2.2 Hydration for Endurance Events: Too Little and Too Much

UNIT 3 • WEEKS 5–6

Nutrition

Timing meals around training, from Bergström and Hultman’s one-legged cycling experiment on muscle glycogen to a fueling timeline the student tests; and Ellen Swallow Richards’s New England Kitchen and a week of family meals planned, priced by unit cost and cooked on a budget.

3.1 Timing Meals for Training

3.2 Cook for a Week on a Budget

UNIT 4 • WEEKS 7–8

Strength

Power and plyometrics, from Yuri Verkhoshansky’s “shock method” and Ray Ewry’s standing jumps to safe landings, a low-volume jump session and a jump-height calculation; and strength for your sport, from Boyd Epley’s weight room to a needs analysis and a light free-weight plan with strength estimated, never maxed.

4.1 Power and Plyometrics

4.2 Strength for Your Sport

UNIT 5 • WEEKS 9–10

Aerobic Training

Lactate threshold and VO_2 max, from A. V. Hill’s oxygen ceiling to Karlman Wasserman’s threshold, with a 12-minute run and a threshold workout; and Billy Mills’s 1964 Olympic 10,000 metres and a race plan with predicted splits, a race and the family fitness day.

5.1 Lactate Threshold and VO_2 Max

5.2 A Race Plan: 5K or 10K

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 Exercise, Mood and Sleep: warm-up, video, teaching and picture study • Session 2: Lesson 1.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it <i>Three short sessions a week is the usual rhythm: one to learn, two to move. Keep moving every day, even on days with no lesson.</i>

WEEK	PLAN
2	• Session 1: Lesson 1.2 Knee and Ankle Injury Prevention: The 11+: warm-up, video, teaching and picture study • Session 2: Lesson 1.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 1 review and unit challenge
3	• Session 1: Lesson 2.1 Heat Acclimatization: The First Two Weeks: warm-up, video, teaching and picture study • Session 2: Lesson 2.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
4	• Session 1: Lesson 2.2 Hydration for Endurance Events: Too Little and Too Much: warm-up, video, teaching and picture study • Session 2: Lesson 2.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 2 review and unit challenge
5	• Session 1: Lesson 3.1 Timing Meals for Training: warm-up, video, teaching and picture study • Session 2: Lesson 3.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
6	• Session 1: Lesson 3.2 Cook for a Week on a Budget: warm-up, video, teaching and picture study • Session 2: Lesson 3.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 3 review and unit challenge
7	• Session 1: Lesson 4.1 Power and Plyometrics: warm-up, video, teaching and picture study • Session 2: Lesson 4.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
8	• Session 1: Lesson 4.2 Strength for Your Sport: warm-up, video, teaching and picture study • Session 2: Lesson 4.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 4 review and unit challenge

WEEK	PLAN
9	• Session 1: Lesson 5.1 Lactate Threshold and VO₂ Max: warm-up, video, teaching and picture study • Session 2: Lesson 5.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
10	• Session 1: Lesson 5.2 A Race Plan: 5K or 10K: warm-up, video, teaching and picture study • Session 2: Lesson 5.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 5 review and unit challenge <i>Last week. Hold a family fitness day: the student leads the family through a warm-up, a favorite activity from each unit and a cool-down, serves a healthy snack and water, and shows the fitness journal.</i>

MATERIALS

Fitness journal (any notebook)

One for the quarter: sleep logs, balance times, heart rates, sweat-rate tables, meal plans and costs, jump and lift logs, splits, reflections.

A timer or stopwatch (a phone timer with a lap button works)

For intervals, balance holds, pulse counts, the 12-minute run and race splits.

Good athletic shoes and comfortable, modest clothes for exercise

Every activity lesson.

A towel or mat, a sturdy bottom stair or step, a wall and a clear, non-slip floor or level grass

For the 11+ exercises, balance tests, landings and strength work.

A broom handle or dowel, a backpack with books and two water jugs

For technique practice and light household loads in Unit 4.

A bathroom scale, a measuring cup and a water bottle

For the sweat-rate test in Lesson 2.2 (only the change is recorded, as fluid lost).

A thermometer or weather app and a printed heat-index chart

For the heat plan in Lesson 2.1.

Food labels, grocery receipts or store price tags, measuring cups and a calculator

For the fueling timeline in Lesson 3.1 and the budget week in Lesson 3.2.

Ordinary groceries for a week of family dinners, chosen with a parent

Lesson 3.2. Use what the family normally buys; no special foods.

Chalk or tape and a tape measure

For the vertical-jump and broad-jump tests and marking a running loop.

A measured running route or track (a map app can measure a loop)

For the 12-minute run, threshold workout and race in Unit 5.

Optional: light dumbbells or a kettlebell

Unit 4, only with a knowledgeable adult present. Water jugs and a backpack work instead.

GRADING

Grades come mostly from the activities and the fitness journal, because fitness is learned by doing, recording and doing again. A student who works hard, trains with good form, records honestly and improves on his or her own numbers earns full credit, whatever those numbers are.

PART	%
Activities (effort, participation, good form and safe habits)	40
Fitness journal (dated logs, calculations, graphs and reflections)	25
Unit reviews	15
Unit challenges	20

Scale: A 90–100, B 80–89, C 70–79, D 60–69. Below 60: repeat the activity or review with help.

- Fitness marks reward effort, consistency and improvement against the student's own earlier numbers. They never depend on body size, body measurements or comparison with other students.
- A journal page earns full marks when it has a date, numbers with units, any calculation shown step by step, an effort rating, a sentence about how it felt and a sentence about what to change next time.

- In the unit reviews, calculations earn partial credit for correct steps even if the final number is off.
- A student who finds sport hard, or who has a health condition that limits some activities, is graded on faithful effort within what the doctor allows. Every body can grow stronger; the goal is faithfulness, not being the best.

A NOTE TO PARENTS

You do not need to be a coach to teach this course. Read the story together, watch the video, and then be the timer, the safety officer and the encourager. An eleventh grader can plan his or her own training, keep the records and run the sessions; your job is to check each plan before the activity, to be present for jumping and free-weight work, and to say plainly when form or rest needs attention. Train alongside your student when you can.

Keep the conversation on what the body can do and how to care for it, never on size or shape. Praise effort, good form, honest records and wise rest. If a teammate or sibling is faster or stronger, steer back to the journal: “Did you beat your own number?” Exercise is good for the body, and Scripture says plainly that godliness is better still (1 Timothy 4:8). We move, eat, drink and rest to the glory of God.

A few lessons touch serious matters plainly, as history and safety require. Lesson 1.1 gives general facts about exercise, mood and sleep; it is not counseling, and if your teen’s sadness, worry or sleep trouble lasts for weeks, talk with your doctor and your pastor. Lesson 2.1 tells how the football player Korey Stringer died of heat stroke in 2001, and Lesson 2.2 tells how a runner died of hyponatremia after the 2002 Boston Marathon; both are told briefly, to teach prevention. Lesson 2.2 uses a bathroom scale before and after exercise; only the difference is recorded, as fluid lost.

UNIT 1

KEEPING ACTIVE

Most of what you know about training is about muscles, heart and lungs. This unit starts with two things that decide whether training works at all: sleep and staying healthy. In 1938 the sleep scientist Nathaniel Kleitman and his student Bruce Richardson lived for a month deep in Mammoth Cave, Kentucky, to find out whether the body's daily rhythm could be stretched to a 28-hour day. Eighty years later a national committee of scientists reviewed hundreds of studies and concluded that regular moderate-to-vigorous activity helps people fall asleep faster and sleep better, and lifts mood. You will learn how the body clock, sleep and exercise work together, and you will keep a sleep and activity log and test how a training session changes your own energy and mood.

Then you will learn to protect the two joints that young athletes injure most: the knee and the ankle. In 2008 Norwegian researchers tested a 20-minute warm-up called the 11+ with nearly 1,900 teenage soccer players and found that severe injuries were roughly halved. You will learn how anterior cruciate ligament (ACL) tears and ankle sprains happen, practice the 11+ with good landing form, and test your balance and landing before and after.

PREREQUISITES

- Knows the activity guideline: at least 60 minutes a day, with muscle- and bone-strengthening on 3 days a week (earlier grades)
- Can find and count a pulse and use a 1–10 effort rating
- Knows a dynamic warm-up and the difference between muscle tiredness and joint pain

MASTERY CHECKLIST

- ☐ I can tell what Kleitman's Mammoth Cave experiment showed about the body clock.
- ☐ I can state what the 2018 *Ph* evidence says about activity, sleep *ysi* and mood, and its limits. *cal*
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- ☐ I can explain how morning light, regular wake times and daily activity help sleep, and how much sleep teenagers need.
- ☐ I can explain how most non-contact ACL injuries and ankle sprains happen and how neuromuscular warm-ups reduce them.
- ☐ I can lead the 11+ warm-up with good landing form and test my balance and landings.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“How Much Sleep Do I Need?” (Nemours KidsHealth for Teens)**: Free. A plain teen article on sleep needs, the teen body clock and sleep habits. Read it with Lesson 1.1.
- **Physical Activity Guidelines for Americans, 2nd edition (U.S. Department of Health and Human Services, 2018)**: Free. The official guidelines, with a chapter on children and adolescents and the health benefits of activity, including sleep. For Lesson 1.1.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

1.1 Exercise, Mood and Sleep

3 sessions of 45–50 minutes

1.2 Knee and Ankle Injury Prevention: The 11+

3 sessions of 45–50 minutes

UNIT 1 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

Describe Kleitman and Richardson’s 1938 Mammoth Cave experiment. What were they testing, what did they measure, and what did they find?

2. **8 pts**

What did the 2018 Physical Activity Guidelines Advisory Committee conclude about physical activity, sleep and mood? Name two findings.

3. **8 pts**

Explain the difference between the circadian clock and sleep pressure, and how exercise and morning light each help sleep.

4. **10 pts**

A student's bedtimes and wake times for five school nights were: 11:00–6:30, 10:30–6:30, 11:30–6:30, 11:15–6:30 and 10:45–6:30. Find the average hours in bed and the total shortfall from a 9-hour target over the five nights.

5. **8 pts**

How much sleep do teenagers need, and why do many teenagers feel sleepy late at night yet struggle to wake in the morning?

6. **8 pts**

Describe the 2008 Norwegian trial of the 11+. Who took part, how was it designed, and what were the results?

7. **8 pts**

Describe the body position in which most non-contact ACL tears happen.

8. **8 pts**

How does a lateral ankle sprain happen, and why does a past sprain raise the risk of another?

9. **8 pts**

Name the three parts of the 11+ and give one exercise from each part.

10. **8 pts**

A team does the 11+ (20 minutes) three times a week for a 10-week season. How many sessions and how many total hours is that? If they do it only once a week, what fraction of the planned sessions is that?

11. **8 pts**

Give three good-form cues for landing from a jump.

12. **10 pts**

In four to six sentences, explain how sleep and injury prevention are connected to training, and how a Christian might think about caring for the body this way.

ANSWER KEY

1. They lived for more than a month in Mammoth Cave, away from daylight, on a 28-hour day (9 hours in bed, 10 working, 9 leisure) and measured body temperature around the clock to see whether the 24-hour rhythm was built in. Kleitman's temperature rhythm stayed close to 24 hours; Richardson's shifted only partly. The body keeps its own roughly 24-hour clock even without sunlight.
2. Any two: regular moderate-to-vigorous activity improves sleep (falling asleep faster, deeper sleep, less waking); it reduces the risk of depression; it reduces symptoms of anxiety; a single session can reduce feelings of anxiety and improve sleep that day.
3. The circadian clock is the brain's roughly 24-hour timer, set mainly by light, which controls melatonin and alertness; sleep pressure is the drive to sleep that builds the longer and more actively you are awake. Morning light sets the clock earlier and strengthens its signal; exercise adds to sleep pressure and also helps the clock. Sleep is best when both say "sleep."
4. Hours: 7.5, 8.0, 7.0, 7.25, 7.75. Total = 37.5 h; average = $37.5 \div 5 = 7.5$ h. Shortfall each night averages $9 - 7.5 = 1.5$ h; over 5 nights = 7.5 h.
5. 8 to 10 hours a night for ages 13–18. During puberty the circadian clock shifts later, so melatonin rises later in the evening; with early school or practice times, teens are often short of sleep and wake during their biological "night."
6. 1,892 female soccer players aged 13–17 in 125 clubs; whole clubs were randomly assigned to do the 11+ or their usual warm-up for an eight-month season, and injuries were recorded. The 11+ group had a significantly lower risk of injuries overall (about one-third lower), overuse injuries (about half) and severe injuries (about half).
7. Landing, stopping or cutting with the foot planted and the knee nearly straight and stiff, collapsing inward (valgus), often with the body's weight behind or off to the side and the hip dropping.
8. The foot rolls inward (often landing on uneven ground or another player's foot), stretching or tearing the ligaments on the outside of the ankle. After a sprain, the ligaments and the joint's proprioception (sense of position) are weaker, so balance training is needed to restore control.
9. Part 1 running drills (e.g., hip out, hip in, circling a partner); Part 2 strength, jumping and balance (e.g., plank, side plank, hamstring lowers, single-leg stand,

squats, jumps); Part 3 running (e.g., running across the field, bounding, plant and cut).

10. $3 \times 10 = 30$ sessions; $30 \times 20 = 600$ minutes = 10 hours. Once a week = 10 sessions = $10 \div 30 = 1/3$ of the plan. (Studies show the benefit depends on doing it faithfully, at least twice a week.)
11. Any three: land softly on the balls of the feet, then heels; bend hips and knees together; keep knees over the second toe, never caving in; chest over knees; land quietly; keep hips level on one leg.
12. Answers vary. Full credit for: muscles repair and adapt during rest and deep sleep, so too little sleep slows progress and may raise injury risk; warm-ups like the 11+ train the nervous system to protect joints; both are part of training, not extras. The body is God's good gift and a temple to care for (1 Corinthians 6:19-20); rest is part of His design (Genesis 2:2-3), and a merry heart is good medicine (Proverbs 17:22), though exercise is not the highest good (1 Timothy 4:8).

UNIT CHALLENGE: TWO WEEKS OF REST AND READINESS

For two weeks, keep your sleep and activity log every day and do the 11+ at least twice a week. In week two, test the one sleep change you chose in Lesson 1.1. At the end, present your log with weekly averages, a graph of hours in bed by night, your balance and landing scores from the first and last 11+ sessions, and one page explaining what you learned: what changed, what did not, and what habit you will keep.

LOOK FOR	WHAT IT MEANS
Complete log	Fourteen days of bedtimes, wake times, rested scores and active minutes, with correct hours-in-bed and average calculations.
Faithful warm-ups	At least four 11+ sessions done at the beginning or intermediate level, dated and timed, with form notes.
Fair test of a change	One clear sleep change, a written prediction, and an honest comparison of week one and week two.
Retest and form	Balance and landing scores recorded before and after, with a parent's note on landing form.
Reflection	A page using the words circadian rhythm, sleep pressure, proprioception and neuromuscular training, judged on effort and honesty, not on the size of the numbers.

1.1 EXERCISE, MOOD AND SLEEP

OBJECTIVES

- Tell what Nathaniel Kleitman's 1938 Mammoth Cave experiment showed about the body's daily rhythm.
- Summarize what the 2018 *Physical Activity Guidelines* evidence says about activity, sleep and mood, and what it does not say.
- Explain how the body clock, sleep pressure, light and exercise work together, and how much sleep teenagers need.
- Keep a week-long sleep and activity log, calculate sleep totals and averages, and test how a training session changes energy and mood.

Warm-up. Walk briskly for 2 minutes, then do 10 arm circles each way, 10 bodyweight squats, 10 walking lunges, 10 high knees on each leg and 30 seconds of skipping in place. Before you start, rate your energy and your mood from 1 to 10; rate them again when you finish. Think about it: did five minutes of movement change either number? What time did you go to bed last night, and what time did you wake up?

WATCH

Exercise and mental health

Demystifying Medicine McMaster · 3:34

https://www.youtube.com/watch?v=CRuKrB_lth8

WHEN TO WATCH

After the “How they figured it out” paragraph. Write down the two or three findings it describes and how much activity it mentions.

Note: A whiteboard-style summary made by McMaster University students with the university’s medical-education program. It explains endorphins by comparing them with the pain medicine morphine and mentions studies of exercise and anxiety and low mood; it is general information, not counseling.

BACKUP VIDEO

Can you change your sleep schedule?

TED-Ed · 4:38

<https://www.youtube.com/watch?v=Amkg1cdDCpM>

After the “How your body works” paragraph, to see the body clock and light explained in cartoons.

KEY TERMS

circadian rhythm

The body’s roughly 24-hour cycle of sleepiness and alertness, body temperature and hormones, run by a master clock in the brain and set each day mainly by light.

sleep pressure

The growing drive to sleep that builds the longer you are awake and the more active your day; it is released during sleep.

melatonin

A hormone released by the brain in the evening, when it is dark, that helps signal that it is time to sleep. Bright light, including screen light, delays it.

deep (slow-wave) sleep

The deepest stage of sleep, most common early in the night, when growth hormone is released and the body does much of its physical repair.

REM sleep

Rapid-eye-movement sleep, more common late in the night, when most vivid dreaming happens; it was discovered in Kleitman's laboratory in 1953.

CORE IDEAS

The story. On June 4, 1938, Nathaniel Kleitman, a physiologist at the University of Chicago, and his graduate student Bruce Richardson climbed down into Mammoth Cave in Kentucky, where no daylight reaches and the temperature stays about the same all year. They set up beds, a table and lamps in a deep chamber and lived there until July 6, more than a month. Their question was simple: is the 24-hour day built into the body, or only a habit? To find out, they lived on a 28-hour “day”: 9 hours in bed, 10 hours of work and 9 hours of leisure, and they took their body temperature again and again around the clock.

How they figured it out. Kleitman knew that body temperature rises and falls in a daily wave, lowest in the early morning and highest in the late afternoon, and that alertness follows it. In the cave, the younger Richardson's temperature rhythm shifted part of the way toward the 28-hour schedule, but Kleitman's stayed close to 24 hours; he lay awake when his old rhythm said “day” and grew sleepy when it said “night.” The experiment showed that the body keeps its own roughly 24-hour clock even without sunlight. Kleitman published the results in 1939 in *Sleep and Wakefulness*, the first great textbook on sleep, and in 1953 his laboratory discovered REM sleep. Much later, in 2018, the U.S. Physical Activity Guidelines Advisory Committee reviewed the research on activity and health. It found strong evidence that regular moderate-to-vigorous activity improves sleep (falling asleep faster, sleeping more deeply and waking less) and reduces the risk of depression and symptoms of anxiety, and that even a single session of activity can reduce feelings of anxiety and improve sleep that same day.

How your body works. Your master clock sits in a small cluster of nerve cells in the hypothalamus, just above where the nerves from your eyes cross. Morning light reaching the eyes sets it each day; in the evening, as light fades, the brain releases melatonin. A second system, **sleep pressure**, builds the longer you are awake and the more active you are. You sleep best when the two line up: a clock that says

“night” and a full tank of sleep pressure. During puberty the clock shifts later, so teens naturally feel sleepy later, yet most still need **8 to 10 hours** of sleep a night, the amount recommended for ages 13–18 by the American Academy of Sleep Medicine and endorsed by the American Academy of Pediatrics. Exercise helps in several ways: it adds to sleep pressure, daytime and outdoor activity strengthen the clock’s signal, and the brain releases chemical messengers such as endorphins, dopamine and serotonin during and after exercise that affect mood. Deep sleep, in turn, is when growth hormone is released and muscles repair, so training and sleep feed each other.

Think it through. Scripture says, “A merry heart doeth good like a medicine” (Proverbs 17:22), and the evidence agrees that an active life helps the heart in both senses. But exercise is one good gift among many, not a cure for everything. Everyone has low days; if sadness, worry or trouble sleeping lasts for weeks, talk with your parents, your pastor and your doctor. Very hard exercise in the hour or two before bed keeps some people awake, and bright screens late at night delay melatonin, so for most teens the best plan is activity earlier in the day, daylight in the morning, a regular wake-up time even on weekends, and screens off about an hour before bed.

Try it. This week you will keep a seven-night sleep log alongside your daily activity minutes, and test how one outdoor training session changes your energy and mood. Worked example: bed at 10:45 p.m. and up at 6:15 a.m. is 7 hours 30 minutes in bed. If your target is 9 hours, you are 1.5 hours short; five school nights like that add up to 7.5 hours, almost a full night’s sleep missing by Friday.

PICTURE STUDY



Breezing Up (A Fair Wind), Winslow Homer, 1873–1876 · Oil on canvas · National Gallery of Art, Washington, D.C.

Image: [Wikimedia Commons](#), public domain

Winslow Homer painted this scene from the fishing town of Gloucester, Massachusetts, where he spent the summer of 1873. A fisherman and three boys sail home in a small catboat, leaning out to balance the boat as the wind fills the sail. When it was shown in 1876, critics praised its fresh air and sunlight, and it became one of the best-loved American paintings.

Look closely

- Look at how each boy is sitting. How is each one using his body to balance the boat?
- Find the man holding the line. What job is he doing, and how does he look?
- Look at the light on the water and the clouds. What time of day might it be?
- Look at the faces. What does this picture tell you about the boys' mood?

Talk about it

1. How might a day like this, out in the wind and sun doing real work, affect how these boys sleep that night?
2. Homer painted bright morning or midday light. How does daylight help set the body clock?

3. What outdoor activity gives you a “merry heart” like this? How could you fit more of it into your week?

Safety first. A parent should know about and supervise all activity; if you have asthma, a heart condition, diabetes, a recent injury or any health concern, check with your doctor before starting this course. Train outdoors with a buddy or adult, away from traffic, in daylight or with reflective clothing, and stop and tell an adult right away at chest pain, dizziness, fainting or trouble breathing. Sleep logs are for building good habits; if trouble sleeping or low mood lasts for weeks, tell your parents and see your doctor.

ACTIVITY

The Sleep and Move Log

You will gather your own evidence. For seven nights you will record when you sleep and how rested you feel, next to how many minutes you were active each day. Twice this week you will rate your energy and mood before and after a 30-minute outdoor session, and at the end you will choose one change to test.

You will need

- Your fitness journal with a seven-day log table (date, bedtime, wake time, hours in bed, rested 1–5, active minutes, vigorous minutes, screens-off time, notes)
- A watch or phone timer
- Good shoes and a safe outdoor loop (a park path, a quiet street with sidewalks, a track)

Steps

1. **Set up the log (Session 2).** Draw the table in your journal. Each morning, fill in last night's bedtime, wake time and a "rested" score (1 = exhausted, 5 = fully rested). Each evening, fill in your active minutes and how many were vigorous (breathing hard, can say only a few words).
2. **Before the session.** Write the time of day, the weather and your energy and mood ratings (1–10). Take your resting pulse for 30 seconds and double it.
3. **The outdoor session (30 minutes).** Walk briskly for 5 minutes. Then do 5 rounds of 3 minutes of easy jogging (you can still talk in sentences) and 1 minute of brisk walking. Finish with 5 minutes of easy walking. If you cannot yet jog for 3 minutes, jog 1 minute and walk 2.
4. **After the session.** Rate energy and mood again, and write one sentence about how you feel. Stretch your calves, thighs, hamstrings and hips for 20–30 seconds each.
5. **Sessions 2 and 3 (two days apart).** Do the same session at the same time of day so the comparison is fair. Morning sessions are best if you can manage them: the daylight helps set your clock.

6. **Do the arithmetic at the end of the week.** For each night, find hours in bed (for example, 10:45 p.m. to 6:15 a.m. = 7 h 30 min = 7.5 h). Add the seven nights and divide by 7 for your average. Subtract it from 9 hours to find your nightly shortfall, and multiply by 7 for the week's total.
7. **Look for patterns.** Make a scatter plot with active minutes on the horizontal axis and the next night's "rested" score on the vertical axis. Do more active days tend to give better nights? Did the training sessions change your mood or energy ratings?
8. **Choose one change and test it next week:** the same wake-up time every day, 10 minutes of morning daylight, screens off 60 minutes before bed, or your hardest training finished at least 2 hours before bed. Write a prediction of what it will do.

Tips

- Be honest. A log that shows a problem is more useful than a log that looks good.
- One week is a small sample. Notice patterns, but do not treat them as proof; the large studies are the proof.
- A regular wake-up time is the single strongest habit for setting your body clock. Sleeping in until noon on Saturday makes Monday morning harder.

Check your work

- ☐ I can explain what Kleitman's cave experiment and the 2018 guidelines evidence showed.
- ☐ I kept a seven-night log and calculated my average sleep and weekly shortfall.
- ☐ I compared my energy and mood before and after two training sessions and chose one change to test.

FITNESS JOURNAL

1. Copy your seven-day log and show the hours-in-bed calculation for each night, the weekly average and the shortfall from 9 hours.
2. Draw your scatter plot of active minutes against the next night's rested score, and write two sentences about what it suggests and why one week cannot prove it.

3. Record both sessions: resting pulse, energy and mood before and after, and one sentence on how each felt.
4. Draw a 24-hour clock face and mark your wake time, morning light, training, last screen time, melatonin rising and bedtime.

From history. Nathaniel Kleitman (1895–1999) lived to be 104 and is often called the father of modern sleep research. In 1953 his student Eugene Aserinsky noticed, while watching sleepers in Kleitman’s laboratory at the University of Chicago, that their eyes moved rapidly at certain times during the night. Together they described rapid-eye-movement (REM) sleep, opening up the scientific study of the stages of sleep.

COMMON MISTAKES

- Thinking teens need less sleep than children. Most teens need 8 to 10 hours, even though their body clock makes them sleepy later.
- “Catching up” by sleeping very late on weekends. It shifts your clock later and makes the week harder; a steady wake-up time works better.
- Training hard late at night and then scrolling on a bright phone in bed. Both can delay sleep.
- Treating exercise as a cure for every low feeling. It helps, but lasting sadness, worry or sleep trouble is a reason to talk with parents, a pastor and a doctor.

Make it a game • Daily Rhythm Debrief. Explain Kleitman's Mammoth Cave experiment and the body's twenty-four-hour rhythm to your parent. Then present your sleep and activity log, separating what the evidence supports from what it does not. She challenges any claim you cannot back up. Define melatonin and sleep pressure. Best evidence-based argument wins the round.

Scripture. “A merry heart doeth good like a medicine: but a broken spirit drieth the bones.” (Proverbs 17:22, KJV)

God made body and spirit to affect each other. Active days, good sleep and thankfulness are part of caring for both.

1.2 KNEE AND ANKLE INJURY PREVENTION: THE 11+

OBJECTIVES

- Tell how the 11+ warm-up was developed and what the 2008 Norwegian trial found.
- Explain how most non-contact ACL injuries and ankle sprains happen, and how strength, balance and landing training reduce them.
- Perform the three parts of the 11+ at the beginning level with good knee alignment and soft landings.
- Test balance and landing form, plan two or three 11+ sessions a week, and retest.

Warm-up. Jog easily for 2 minutes. Then do 10 leg swings forward and back and 10 side to side on each leg, 10 walking lunges, 10 squats and 10 calf raises. Stand on one foot for 20 seconds, then the other. Think about it: when you land from a jump or stop suddenly, which way do your knees want to go? Have you ever rolled an ankle? What were you doing?

WATCH

ACL Prevention Exercises – FIFA 11 Presented by Dr. Momaya

Amit Momaya MD · 6:06

https://www.youtube.com/watch?v=X_rYikdh2JM

WHEN TO WATCH

In Session 2, before the activity. Watch each exercise, then pause and practice the beginning level with a partner watching your knees.

Note: Dr. Amit Momaya, Chief of Sports Medicine at the University of Alabama at Birmingham, introduces the 11+, and soccer players in T-shirts and shorts demonstrate the running exercises, planks, side planks, hamstring lowers, single-leg balance, squats and lunges on a stadium field. A small channel, chosen because it comes from a university sports-medicine physician and shows the whole program clearly.

BACKUP VIDEO

ACL Injury Prevention: Jumping and Landing Technique

Hospital for Special Surgery · 2:56

<https://www.youtube.com/watch?v=ICxMeAhj8A0>

After the “How your body works” paragraph, to see good and poor landings side by side.

KEY TERMS

anterior cruciate ligament (ACL)

A strong band inside the knee that connects the thighbone to the shinbone and keeps the shin from sliding forward or twisting too far.

knee valgus

The knee collapsing inward toward the other knee, often with the hip dropping and the foot turning out; the most dangerous landing position for the ACL.

non-contact injury

An injury that happens without a collision, usually when landing, stopping or cutting. Most ACL tears are non-contact.

lateral ankle sprain

A stretch or tear of the ligaments on the outside of the ankle when the foot rolls inward, the most common sports injury.

neuromuscular training

Exercises that train the nervous system and muscles together (strength, balance, jumping and landing, cutting) so the body controls joints automatically.

proprioception

Your body's sense of where your joints are and how they are moving, from sensors in muscles, tendons and ligaments; balance training sharpens it.

CORE IDEAS

The story. Soccer is the world's most played sport, and knee and ankle injuries are its most common serious ones. In the early 2000s the medical research centre of FIFA, soccer's world governing body, worked with the Oslo Sports Trauma Research Center in Norway and the Santa Monica Orthopaedic and Sports Medicine Research Foundation in California to design a short warm-up that any team could do without equipment. The result, released in 2006, was the 11+: about 20 minutes of running drills, strength, balance and jumping exercises, done at the start of practice.

How they figured it out. A program is only worth teaching if it works, so the Norwegian researchers tested it fairly. Torbjørn Soligard and his colleagues enrolled 125 girls' soccer clubs, 1,892 players aged 13 to 17, and randomly assigned whole clubs either to do the 11+ or to warm up as usual for an eight-month season. Coaches recorded every injury. The results, published in the *BMJ* in December 2008, showed that the 11+ clubs had a significantly lower risk of injury overall (about a third lower), of overuse injuries (about half) and of severe injuries (also roughly half). Later studies in boys, men and other sports found similar benefits, and found that teams who did the program faithfully, at least twice a week, gained the most.

How your body works. About two-thirds or more of ACL tears happen without contact, in a split second of landing, stopping or cutting. The danger position is a stiff, nearly straight knee that collapses inward (**valgus**) while the body's weight is behind or off to the side and the foot is planted. Female athletes tear the ACL several times as often as male athletes in the same sports, which is one reason the first trial studied girls. Ankle sprains usually happen when the foot lands rolled inward, for example on another player's foot, stretching the ligaments on the outside of the ankle; the biggest risk factor for a sprain is a previous sprain, because the joint's sense of position (**proprioception**) is weaker afterward. Neuromuscular training works on all of this: strong hips and thighs keep the knee lined up over the toes, strong hamstrings protect the ACL, balance training sharpens proprioception,

and practiced landings become automatic, so in a game your body lands well without thinking.

Good form. Land softly on the balls of your feet, then let your heels come down. Bend your hips and knees together, “like sitting into a chair,” chest over knees. Keep your knees pointing over your second toe, never caving in. Make landings quiet: loud landings mean stiff legs. On one leg, keep your hip level and your knee over your foot.

Try it. This week you will test your balance and landing, learn and do the full 11+ at the beginning level, and retest. Worked numbers: the 11+ takes about 20 minutes. Done twice a week for an 8-week season, that is 16 sessions, or 320 minutes, about 5 hours 20 minutes in all, a small price for halving the chance of a severe injury.

PICTURE STUDY



The Football Players, Henri Rousseau, 1908 · Oil on canvas · Solomon R. Guggenheim Museum, New York

Image: [Wikimedia Commons](#), public domain

Henri Rousseau worked for years as a toll collector in Paris and taught himself to paint. Here, in 1908, he painted men playing a rugby-style football game in a park, in matching striped suits. The poses are stiff and dreamlike, but the painting is full of jumping, reaching and landing, the very moments when knees and ankles are most at risk.

Look closely

- Look at the man leaping for the ball. How will he land? Where should his knees be?
- Find the player on the far left reaching for another's shoulders. What happens to a player's balance when he is pushed in the air?
- Look at each man's feet and legs. Which one looks most balanced? Which looks least?
- Look at the ground. Is it smooth or uneven? How does the playing surface affect ankle injuries?

Talk about it

1. Which moments in this game would put the most strain on the ACL: the leap, the landing, the push or a sudden change of direction?

2. These players have no warm-up area and no trainer. What could they do before the game to protect their knees and ankles?
3. Choose one 11+ exercise that would help the player in the center most. Explain why.

Safety first. Do the 11+ on level grass or a non-slip floor in good shoes, with enough room to run and cut safely. Learn each exercise at the beginning level and move up only when your knees stay over your toes and your landings are soft; stop at any sharp or joint pain. If you have had a knee or ankle injury, check with your doctor or physical therapist before the jumping exercises.

ACTIVITY

Test, Train, Retest: The 11+

You will measure your balance and landing, learn the whole 11+ warm-up, do it on both activity days, and plan how to keep it going for the rest of your season.

A helper with a phone camera makes the landing check much better.

You will need

- Six markers (cones, cups or shoes) set in two parallel lines about 6 yards apart, forming a lane about 20–30 yards long
- A stopwatch and a helper with a phone that can film in slow motion
- A mat or towel and a partner (or a heavy couch edge) to hold your heels for the hamstring exercise
- Your fitness journal

Steps

1. **Balance test (before).** Stand barefoot on one leg, hands on hips, the other foot lifted beside your ankle. Close your eyes and start the watch. Stop when you open your eyes, touch down or move your hands, or at 30 seconds. Do 3 tries on each leg and record the best.
2. **Landing check (before).** Stand on a bottom stair or sturdy step about 12 inches high. Step (do not jump) off, land on both feet, and immediately jump straight up as high as you can, landing softly. Your helper films from the front in slow motion. Do 3. Watch the film: do your knees cave in on landing? Is the landing loud? Score each landing 0 (knees stay over toes, soft) to 2 (knees cave clearly, stiff). Record your total.
3. **11+ Part 1: running (about 8 minutes).** Jog the lane and back for each drill, twice: straight ahead; hip out (lift each knee and open it outward as you go); hip in; circling a partner (or a marker) with small sideways steps; jumping with a shoulder bump in the air (or a jump and soft two-foot landing if alone); quick forward and backward runs. Keep your knees over your toes on every step and stop.
4. **11+ Part 2: strength, jumping and balance (about 10 minutes), beginning level.** (1) Plank on forearms, 3 × 20–30 seconds. (2) Side plank from the knees

or feet, 3 × 20–30 seconds each side. (3) Hamstring lowers (Nordic): kneel with a partner holding your ankles and lower your upper body slowly forward as far as you can control, catching yourself with your hands, 3–5 reps. (4) Single-leg stand holding a ball, 2 × 30 seconds each leg. (5) Squats with toe raises, 2 × 30 seconds. (6) Vertical jumps: jump straight up and land softly on both feet, 2 × 30 seconds, resting between jumps.

5. **11+ Part 3: running (about 2 minutes).** Run across the lane at about 75–80% of top speed, twice; bound with high knee lift, twice; plant and cut: run 5 steps, plant on the outside foot with the knee bent and over the toes, and change direction, twice each side.
6. **Log it.** Record the time the whole warm-up took, your effort rating and which exercises were hardest.
7. **Session 3: repeat and retest.** Do the full 11+ again with better form. Then repeat the balance test and the landing check exactly as before, and compare your numbers.
8. **Plan your season.** Write a schedule to do the 11+ at least twice a week for the next 8 weeks, at the start of practice or before your own runs. Mark when you will move to the intermediate level of each Part 2 exercise (when the beginning level feels easy with perfect form).

Tips

- Quality beats speed. A slow, perfect squat teaches the knee more than a fast, sloppy one.
- Balance numbers improve quickly in the first weeks; that is your nervous system learning.
- If you play a team sport, offer to lead the 11+ for your team or a younger sibling's team.

Check your work

- ☐ I can explain how non-contact ACL injuries and ankle sprains happen and what the 2008 trial found.
- ☐ I can do all three parts of the 11+ with knees over toes and soft landings.
- ☐ I tested and retested balance and landing, and planned at least two sessions a week.

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1. Record your balance times (best of 3, each leg) and landing scores for both days, with the change.
2. Draw the right knee from the front, labeling the thighbone, shinbone, kneecap and ACL, and sketch a “good” and a “valgus” landing as stick figures.
3. Write the 11+ as a one-page card you could tape to a fence: parts, exercises, times and one form cue for each.
4. Copy your eight-week 11+ schedule and tick off each session as you do it.

From history. The original trial studied girls, but the 11+ has since been tested in boys, adult men and women, and amateur and professional players, and a version called the 11+ Kids was later designed for children under 14. FIFA translated the program into many languages and published it free so that any coach anywhere could use it.

COMMON MISTAKES

- Letting the knees cave in on landings and cuts. Knees track over the second toe, every time.
- Landing with straight, stiff legs. Bend at hips and knees together, and land quietly.
- Doing the program once and stopping. The benefit comes from doing it at least twice a week all season.
- Skipping the hamstring exercise because it is hard. Strong hamstrings are one of the knee’s best protectors.

Make it a game • Land Clean Challenge. Perform the 11+ style warm-up: single-leg balance, hops and soft landings. Your parent watches the knees and calls knee valgus when she sees it. Count clean landings out of ten. Explain how non-contact ACL injuries happen. Retest after a week and aim for a higher score. Tell the Norwegian trial story.

UNIT 1

KEEPING ACTIVE

Most of what you know about training is about muscles, heart and lungs. This unit starts with two things that decide whether training works at all: sleep and staying healthy. In 1938 the sleep scientist Nathaniel Kleitman and his student Bruce Richardson lived for a month deep in Mammoth Cave, Kentucky, to find out whether the body's daily rhythm could be stretched to a 28-hour day. Eighty years later a national committee of scientists reviewed hundreds of studies and concluded that regular moderate-to-vigorous activity helps people fall asleep faster and sleep better, and lifts mood. You will learn how the body clock, sleep and exercise work together, and you will keep a sleep and activity log and test how a training session changes your own energy and mood.

Then you will learn to protect the two joints that young athletes injure most: the knee and the ankle. In 2008 Norwegian researchers tested a 20-minute warm-up called the 11+ with nearly 1,900 teenage soccer players and found that severe injuries were roughly halved. You will learn how anterior cruciate ligament (ACL) tears and ankle sprains happen, practice the 11+ with good landing form, and test your balance and landing before and after.

PREREQUISITES

- Knows the activity guideline: at least 60 minutes a day, with muscle- and bone-strengthening on 3 days a week (earlier grades)
- Can find and count a pulse and use a 1–10 effort rating
- Knows a dynamic warm-up and the difference between muscle tiredness and joint pain

MASTERY CHECKLIST

- ☐ I can tell what Kleitman's Mammoth Cave experiment showed about the body clock.
- ☐ I can state what the 2018 *Ph* evidence says about activity, sleep *ysi* and mood, and its limits. *cal*
Ac
tiv
ity
Gu
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lin
es
- ☐ I can explain how morning light, regular wake times and daily activity help sleep, and how much sleep teenagers need.
- ☐ I can explain how most non-contact ACL injuries and ankle sprains happen and how neuromuscular warm-ups reduce them.
- ☐ I can lead the 11+ warm-up with good landing form and test my balance and landings.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“How Much Sleep Do I Need?” (Nemours KidsHealth for Teens)**: Free. A plain teen article on sleep needs, the teen body clock and sleep habits. Read it with Lesson 1.1.
- **Physical Activity Guidelines for Americans, 2nd edition (U.S. Department of Health and Human Services, 2018)**: Free. The official guidelines, with a chapter on children and adolescents and the health benefits of activity, including sleep. For Lesson 1.1.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

1.1 Exercise, Mood and Sleep

3 sessions of 45–50 minutes

1.2 Knee and Ankle Injury Prevention: The 11+

3 sessions of 45–50 minutes

UNIT 1 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

Describe Kleitman and Richardson’s 1938 Mammoth Cave experiment. What were they testing, what did they measure, and what did they find?

2. **8 pts**

What did the 2018 Physical Activity Guidelines Advisory Committee conclude about physical activity, sleep and mood? Name two findings.

3. **8 pts**

Explain the difference between the circadian clock and sleep pressure, and how exercise and morning light each help sleep.

4. **10 pts**

A student's bedtimes and wake times for five school nights were: 11:00–6:30, 10:30–6:30, 11:30–6:30, 11:15–6:30 and 10:45–6:30. Find the average hours in bed and the total shortfall from a 9-hour target over the five nights.

5. **8 pts**

How much sleep do teenagers need, and why do many teenagers feel sleepy late at night yet struggle to wake in the morning?

6. **8 pts**

Describe the 2008 Norwegian trial of the 11+. Who took part, how was it designed, and what were the results?

7. **8 pts**

Describe the body position in which most non-contact ACL tears happen.

8. **8 pts**

How does a lateral ankle sprain happen, and why does a past sprain raise the risk of another?

9. **8 pts**

Name the three parts of the 11+ and give one exercise from each part.

10. **8 pts**

A team does the 11+ (20 minutes) three times a week for a 10-week season. How many sessions and how many total hours is that? If they do it only once a week, what fraction of the planned sessions is that?

11. **8 pts**

Give three good-form cues for landing from a jump.

12. **10 pts**

In four to six sentences, explain how sleep and injury prevention are connected to training, and how a Christian might think about caring for the body this way.

ANSWER KEY

1. They lived for more than a month in Mammoth Cave, away from daylight, on a 28-hour day (9 hours in bed, 10 working, 9 leisure) and measured body temperature around the clock to see whether the 24-hour rhythm was built in. Kleitman's temperature rhythm stayed close to 24 hours; Richardson's shifted only partly. The body keeps its own roughly 24-hour clock even without sunlight.
2. Any two: regular moderate-to-vigorous activity improves sleep (falling asleep faster, deeper sleep, less waking); it reduces the risk of depression; it reduces symptoms of anxiety; a single session can reduce feelings of anxiety and improve sleep that day.
3. The circadian clock is the brain's roughly 24-hour timer, set mainly by light, which controls melatonin and alertness; sleep pressure is the drive to sleep that builds the longer and more actively you are awake. Morning light sets the clock earlier and strengthens its signal; exercise adds to sleep pressure and also helps the clock. Sleep is best when both say "sleep."
4. Hours: 7.5, 8.0, 7.0, 7.25, 7.75. Total = 37.5 h; average = $37.5 \div 5 = 7.5$ h. Shortfall each night averages $9 - 7.5 = 1.5$ h; over 5 nights = 7.5 h.
5. 8 to 10 hours a night for ages 13–18. During puberty the circadian clock shifts later, so melatonin rises later in the evening; with early school or practice times, teens are often short of sleep and wake during their biological "night."
6. 1,892 female soccer players aged 13–17 in 125 clubs; whole clubs were randomly assigned to do the 11+ or their usual warm-up for an eight-month season, and injuries were recorded. The 11+ group had a significantly lower risk of injuries overall (about one-third lower), overuse injuries (about half) and severe injuries (about half).
7. Landing, stopping or cutting with the foot planted and the knee nearly straight and stiff, collapsing inward (valgus), often with the body's weight behind or off to the side and the hip dropping.
8. The foot rolls inward (often landing on uneven ground or another player's foot), stretching or tearing the ligaments on the outside of the ankle. After a sprain, the ligaments and the joint's proprioception (sense of position) are weaker, so balance training is needed to restore control.
9. Part 1 running drills (e.g., hip out, hip in, circling a partner); Part 2 strength, jumping and balance (e.g., plank, side plank, hamstring lowers, single-leg stand,

squats, jumps); Part 3 running (e.g., running across the field, bounding, plant and cut).

10. $3 \times 10 = 30$ sessions; $30 \times 20 = 600$ minutes = 10 hours. Once a week = 10 sessions = $10 \div 30 = 1/3$ of the plan. (Studies show the benefit depends on doing it faithfully, at least twice a week.)
11. Any three: land softly on the balls of the feet, then heels; bend hips and knees together; keep knees over the second toe, never caving in; chest over knees; land quietly; keep hips level on one leg.
12. Answers vary. Full credit for: muscles repair and adapt during rest and deep sleep, so too little sleep slows progress and may raise injury risk; warm-ups like the 11+ train the nervous system to protect joints; both are part of training, not extras. The body is God's good gift and a temple to care for (1 Corinthians 6:19-20); rest is part of His design (Genesis 2:2-3), and a merry heart is good medicine (Proverbs 17:22), though exercise is not the highest good (1 Timothy 4:8).

UNIT CHALLENGE: TWO WEEKS OF REST AND READINESS

For two weeks, keep your sleep and activity log every day and do the 11+ at least twice a week. In week two, test the one sleep change you chose in Lesson 1.1. At the end, present your log with weekly averages, a graph of hours in bed by night, your balance and landing scores from the first and last 11+ sessions, and one page explaining what you learned: what changed, what did not, and what habit you will keep.

LOOK FOR	WHAT IT MEANS
Complete log	Fourteen days of bedtimes, wake times, rested scores and active minutes, with correct hours-in-bed and average calculations.
Faithful warm-ups	At least four 11+ sessions done at the beginning or intermediate level, dated and timed, with form notes.
Fair test of a change	One clear sleep change, a written prediction, and an honest comparison of week one and week two.
Retest and form	Balance and landing scores recorded before and after, with a parent's note on landing form.
Reflection	A page using the words circadian rhythm, sleep pressure, proprioception and neuromuscular training, judged on effort and honesty, not on the size of the numbers.

HYDRATION

Every August, high-school athletes across the country start practice in the hottest weeks of the year. The body can learn to handle heat, but it needs about two weeks to do it. In 2001 the Minnesota Vikings lineman Korey Stringer died of exertional heat stroke after a training-camp practice, and his death led to the Korey Stringer Institute at the University of Connecticut and to national guidelines that ease high-school athletes into hot-weather practice over 14 days. In this unit you will learn what changes inside the body during heat acclimatization, how to recognize heat illness, why the rule is “cool first, transport second,” and how to write a heat plan for your own sport.

Then you will look at the opposite danger. For years endurance athletes were told to drink as much as they could. After the 2002 Boston Marathon, a study of 488 finishers found that 13 percent had low blood sodium, mostly from drinking more than they sweated, and one young runner died of it. You will learn how fluid and sodium balance work, why both too little and too much fluid are harmful, and how to measure your own sweat rate to build a drinking plan for a long event.

PREREQUISITES

- Knows what water does in the body and the signs of dehydration (earlier grades)
- Knows that sweat contains sodium and other electrolytes, and how sweating cools the body
- Can take a pulse, use an effort rating and convert between ounces, cups and liters

MASTERY CHECKLIST

- ☐ I can describe the main body changes of heat acclimatization and why the first 14 days must be gradual.
- ☐ I can recognize heat exhaustion and exertional heat stroke and explain “cool first, transport second.”
- ☐ I can read a heat-index chart and write a heat plan for practice.
- ☐ I can explain exercise-associated hyponatremia: what causes it, its signs and how to prevent it.
- ☐ I can measure my sweat rate and build a drinking plan that avoids both too little and too much.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **Heat acclimatization (Korey Stringer Institute, University of Connecticut):** Free. The institute's plain summary of heat acclimatization for secondary-school athletes, with the 14-day guidelines. For Lesson 2.1.
- **A reusable water bottle with ounce or milliliter marks:** Makes the sweat-rate test and drinking plan in Lesson 2.2 easier. A measuring cup works just as well.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

2.1 Heat Acclimatization: The First Two Weeks

3 sessions of 45–50 minutes

2.2 Hydration for Endurance Events: Too Little and Too Much

3 sessions of 45–50 minutes

UNIT 2 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. 8 pts

Tell the story of Korey Stringer and name two changes in athlete heat safety that followed it.

2. 10 pts

List four body changes that happen during heat acclimatization, and say roughly how long acclimatization takes.

3. 8 pts

Summarize the 2009 high-school heat-acclimatization guidelines for days 1–5.

4. 10 pts

Compare heat exhaustion and exertional heat stroke. What is the first-aid rule for heat stroke, and why?

5. (6 pts)

Using the heat-index chart, the temperature is 90°F and the relative humidity 60 percent. What is the heat index, and why does humidity matter?

6. (8 pts)

What did Almond's study of the 2002 Boston Marathon find? Give the two percentages and the strongest risk factor.

7. (8 pts)

Explain why drinking far more than you sweat can cause brain swelling.

8. (10 pts)

A student's scale reading dropped 2 pounds during a 90-minute run. She drank 20 ounces and passed 4 ounces of urine. Find her fluid lost and her sweat rate in ounces per hour and liters per hour.

9. (8 pts)

Using the student in question 8, write a drinking plan for a 2-hour event in similar weather. How much should she drink per hour, and how often?

10. (6 pts)

A runner finishes a slow 5-hour marathon and the scale shows he is 2 pounds heavier than at the start. What does this suggest, and what should he watch for?

11. (8 pts)

In three to five sentences, explain how Proverbs 25:16 applies to drinking during long exercise.

12. (10 pts)

In four to six sentences, compare the dangers of the first hot week of preseason with the dangers of a long, slow endurance event. How would your planning differ?

ANSWER KEY

1. Stringer, a Minnesota Vikings lineman, collapsed after a hot practice at training camp in Mankato on July 31, 2001, and died of exertional heat stroke on August 1, age 27. Changes: the Korey Stringer Institute at UConn (2010); 14-day heat-acclimatization guidelines for high schools (2009) and state rules adopting them; emergency plans with cold-water immersion tubs at practices.
2. Any four: plasma volume increases; heart rate at the same pace falls; sweating starts sooner; sweat rate increases; sweat becomes less salty; core temperature stays lower; exercise feels easier. About 10–14 days, with most change in the first week.
3. No more than one practice a day, of up to 3 hours; intensity and equipment increased gradually (in football, helmets only on days 1–2, helmets and shoulder pads on days 3–5); no double-practice days until after day 5.
4. Heat exhaustion: weakness, dizziness, headache, nausea, heavy sweating, normal thinking; rest in shade, cool, sip fluids. Heat stroke: core temperature above about 104°F (40°C) with confusion, odd behavior or collapse; a life-threatening emergency. Rule: call 911 and cool first (cold-water immersion), transport second, because the time spent overheated decides survival; nearly everyone survives when cooled immediately.
5. About 100°F. High humidity slows sweat evaporation, so the body cools less effectively and feels hotter.
6. Of 488 runners tested at the finish, 13% had hyponatremia (sodium ≤ 135 mmol/L) and 0.6% had critical hyponatremia (≤ 120). The strongest risk factor was weight gain during the race (drinking more than was sweated); race times over 4 hours also raised the risk.
7. Extra water dilutes blood sodium; by osmosis water moves into cells, which swell. The brain is enclosed in bone, so swelling raises pressure, causing headache, nausea, confusion, seizures and possibly death. The kidneys can pass only about 0.8–1 L an hour, less when ADH stays high during exercise.
8. Fluid lost = $2 \times 16 + 20 - 4 = 48$ oz. Sweat rate = $48 \div 1.5 \text{ h} = 32 \text{ oz/h} \approx 32 \times 0.03 \approx 0.95 \text{ L/h}$ (about 1 liter per hour).
9. About half to three-quarters of 32 oz/h, so roughly 16–24 oz per hour, in small amounts (about 4–6 oz every 15 minutes or 5–8 oz every 20 minutes), never more than 32 oz per hour; start hydrated; add salty food or a sports drink after the first hour.

10. He drank more than he lost, about 32 oz extra, raising the risk of hyponatremia. Watch for headache, nausea, vomiting, swelling, confusion; he should not drink more plain water and should get medical help if symptoms appear.
11. Answers vary. Full credit for: even good things like water should be taken in the right measure; too little fluid harms performance and safety, but too much dilutes blood sodium and can be fatal; wisdom means drinking to thirst or a sweat-rate plan, never far beyond losses; self-control is part of caring for the body God gave.
12. Answers vary. Full credit for: early preseason risks exertional heat stroke and dehydration in unacclimatized athletes, so plan a gradual 14-day progression, cool times of day, shade, water breaks, a heat-index rule and a cold-water tub; a long slow event risks hyponatremia from overdrinking (and dehydration in heat), so plan from a measured sweat rate, drink no more than losses, add sodium in long events, and check that you do not finish heavier.

UNIT CHALLENGE: MY HEAT AND HYDRATION PLAN

Put together a personal heat and hydration plan for your sport or training. Include your 14-day heat-acclimatization schedule, your heat-index rule, your emergency card, both fixed-pace tests from Lesson 2.1, both sweat-rate tests from Lesson 2.2 with calculations, and your 2-hour event drinking plan. Finish with a page explaining the science behind each part of your plan.

LOOK FOR	WHAT IT MEANS
Sound heat plan	A day-by-day 14-day schedule that follows the guidelines, with times of day, breaks and a heat-index rule.
Emergency readiness	A clear emergency card and a family rehearsal of calling 911 and cold-water cooling, with the tub-filling time recorded.
Accurate measurements	Two sweat-rate tests with every calculation shown, recording only fluid lost.
Safe drinking plan	A timeline that replaces most but never more than measured losses, with warning signs for too little and too much.
Explanation	A page using the words acclimatization, plasma volume, heat stroke, hyponatremia and osmosis, judged on understanding and effort.

2.1 HEAT ACCLIMATIZATION: THE FIRST TWO WEEKS

OBJECTIVES

- Tell the story of Korey Stringer and how it changed heat safety for athletes.
- Describe the changes of heat acclimatization (plasma volume, heart rate, sweating, core temperature) and their time course.
- Recognize heat cramps, heat exhaustion and exertional heat stroke, and explain why cold-water immersion comes first.
- Read a heat-index chart, run a fixed-pace test, and write a 14-day heat plan and an emergency plan.

Warm-up. Walk briskly for 2 minutes, then do 10 squats, 10 lunges on each leg, 10 arm circles each way and 1 minute of easy jogging in place. Take your pulse for 15 seconds and multiply by 4. Think about it: why does the first hot practice of the summer feel so much harder than the same practice two weeks later?

WATCH

Korey Stringer Institute Heat and Hydration

Korey Stringer (Korey Stringer Institute) • 10:42

<https://www.youtube.com/watch?v=lztHtCgJwBM>

WHEN TO WATCH

After the “How they figured it out” paragraph. Take notes on the acclimatization schedule, the signs of each heat illness and the cooling steps.

Note: Made for coaches by the Korey Stringer Institute and filmed by USA Football. It shows high-school football players in practice gear and a demonstration of cold-water immersion. It mentions weighing athletes before and after practice to track fluid loss.

BACKUP VIDEO

Heat Preparedness and Hydration : Heat Acclimatization

USA Football • 1:40

<https://www.youtube.com/watch?v=fkgw5z2Z6f4>

A short review of the 14-day plan, before you write your own.

KEY TERMS

heat acclimatization

The set of changes that make the body better at exercising in heat, built by gradually increasing exercise in hot conditions over about 10 to 14 days.

core temperature

The temperature deep inside the body, normally about 98.6°F (37°C). Above about 104°F (40°C) during exercise, with confusion or collapse, is exertional heat stroke.

cold-water immersion

Cooling an overheated athlete by placing the body up to the neck in a tub of ice water, the fastest method; the rule is “cool first, transport second.”

plasma volume

The amount of the liquid part of the blood. It rises early in acclimatization, giving the heart more blood to pump to both muscles and skin.

exertional heat stroke

A life-threatening emergency in which the body overheats during exercise, with core temperature above about 104°F (40°C) and signs of brain dysfunction such as confusion, odd behavior or collapse.

heat index

A number from the National Weather Service that combines air temperature and humidity to show how hot it feels; high humidity slows sweat evaporation.

CORE IDEAS

The story. Korey Stringer was an All-Pro offensive tackle for the Minnesota Vikings. On July 31, 2001, during the team’s preseason training camp in Mankato, Minnesota, he collapsed after a hot, humid morning practice in full pads. He had struggled the day before as well. He was taken to the hospital with a very high body temperature and died early the next morning, August 1, at age 27. He was the first NFL player to die of heat stroke. His wife, Kelci Stringer, worked for years to turn the loss into prevention, and in 2010 the Korey Stringer Institute opened at the University of Connecticut, led by the heat-illness researcher Douglas Casa, to prevent sudden death in sport.

How they figured it out. Physiologists had studied soldiers, miners and athletes working in heat for decades, and they knew that bodies adapt to heat when exposure is gradual. The danger is the first days of preseason, when unacclimatized athletes in heavy equipment are pushed hard. In 2009 a national task force led by Casa

published heat-acclimatization guidelines for high-school athletics: a 14-day period in which, for the first 5 days, athletes have no more than one practice a day of up to 3 hours; football players wear helmets only on days 1 and 2, add shoulder pads on days 3 to 5, and go to full gear on day 6; double-practice days start only after day 5 and are followed by a single-practice or rest day. Many states have since adopted rules like these, and the institute tracks how well each state protects its athletes.

How your body works. Working muscles make a great deal of heat, and the body sheds it mainly by pumping warm blood to the skin and evaporating sweat. In a hot, humid environment, the heart must supply both the muscles and the skin, and sweat evaporates poorly, so core temperature climbs. With 10 to 14 days of gradual exercise in the heat, the body changes: **plasma volume** expands within the first several days; heart rate at the same pace drops; sweating starts sooner and is heavier; sweat becomes less salty, saving sodium; core temperature stays lower; and the same work feels easier. Most of the change comes in the first week, and it begins to fade after a week or two away from the heat. Heat illness ranges from **heat cramps** (painful muscle spasms) to **heat exhaustion** (weakness, dizziness, headache, nausea, heavy sweating; rest in shade, cool, sip fluids) to **exertional heat stroke**: core temperature above about 104°F (40°C) with confusion, odd behavior, stumbling or collapse. Heat stroke is an emergency, and almost everyone survives when cooling begins right away, so the rule is **cool first, transport second**: call 911, get the athlete into a tub of ice water up to the neck (or use rotating ice-water towels and a hose if no tub), and keep cooling until medical staff take over.

Think it through. “The sun shall not smite thee by day” (Psalm 121:6) is a promise of God’s keeping, and God also gives us wisdom to plan. Practices in heat should be early or late in the day, with shade, water breaks and rest, and the hardest work saved until athletes are acclimatized. Read the heat index: at 90°F with 60 percent humidity, the National Weather Service chart gives a heat index of about 100°F, and in full sun it can feel hotter still. Many schools also use the wet-bulb globe temperature, which adds sun and wind, to decide when to change or cancel practice.

Try it. This week you will run a fixed-pace test twice and record heart rate, effort and conditions, write a 14-day acclimatization plan for your own sport or training, and practice a heat emergency plan with your family.

PICTURE STUDY



Haymaking, Jules Bastien-Lepage, 1877 · Oil on canvas · Musée d'Orsay, Paris

Image: [Wikimedia Commons](#), public domain

Jules Bastien-Lepage grew up in the village of Damvillers in northeastern France and painted its farm people. Here two haymakers rest at midday in the heat of a summer harvest. The woman sits dazed with fatigue; the man sleeps with his hat over his face. Haying was heavy work done in the hottest weeks of the year, and farm workers learned to start early and rest at noon.

Look closely

- Look at the woman's face, hands and posture. How tired is she? What might she be feeling?
- Find the sleeping man. Why has he put his hat over his face?
- Look at the color of the field and sky. What does the light tell you about the heat?
- Find the food pail. What else would harvesters need at midday?

Talk about it

1. Why did farm workers rest at noon? How is that like scheduling practice early or late in the day?
2. Harvesters worked in the heat every summer. How would their bodies have changed in the first two weeks of the harvest?

3. What signs would tell you that a worker or athlete in this heat was moving from tiredness toward heat illness?

Safety first. Do the fixed-pace test in the coolest safe part of the day, in shade if you can, with water and a buddy, and skip it if the heat index is above about 90°F. Stop at once and cool down in the shade if you feel dizzy, nauseated, confused or unusually weak, or if you stop sweating; confusion or collapse in the heat is an emergency: call 911 and cool the person in cold water immediately.

ACTIVITY

The Fixed-Pace Test and My Heat Plan

A body that is adapting to heat (or simply getting fitter) does the same work at a lower heart rate. You will run a fixed-pace test twice and record the conditions carefully, then write a real 14-day heat plan for your sport and practice what to do in a heat emergency.

You will need

- A measured loop (a track or a loop measured with a map app) and a stopwatch
- A thermometer or weather app showing temperature and relative humidity, and a printed National Weather Service heat-index chart
- Water, a towel, a cooler or large tub, ice and a hose or buckets (for the emergency practice)
- Your fitness journal

Steps

1. **Record the conditions (Session 2).** Write the time, temperature, humidity and heat index from the chart, and whether you are in sun or shade. Note your urine color (pale straw is the goal) and how much you drank in the last 2 hours.
2. **Fixed-pace test (20 minutes).** After a 5-minute walk, jog the loop at an easy, steady pace you can hold for 20 minutes while talking in sentences. Time each lap and keep the laps within 5 seconds of each other. At 10 and 20 minutes, stop briefly and take your pulse for 15 seconds $\times$ 4. Record your effort rating at the end.
3. **Cool down and drink.** Walk 5 minutes, drink water to thirst, and note how much you sweated (dry, damp, soaked).
4. **Session 3: repeat.** Run the same loop at the same lap pace, at about the same time of day. Compare heart rates at 10 and 20 minutes. If it was hotter or more humid, expect a higher heart rate at the same pace; that is the heat's extra load.

5. **Write your 14-day plan.** For your sport (or your own summer running), make a day-by-day table for the first two weeks: practice length, intensity, equipment, time of day, water breaks (at least every 15–20 minutes in heat) and which days are single or double sessions. Follow the guidelines: days 1–5 one session of no more than 3 hours, intensity and equipment increased gradually, no back-to-back double days.
6. **Write a heat-index rule.** Using the chart, decide what you will change at each level: for example, normal practice below 90°F heat index; more breaks and shade from 90–103°F; shorter, lighter practice with no heavy equipment from 103–115°F; move indoors or cancel above that. Show one example reading from the chart.
7. **Practice the emergency plan.** With your family, rehearse: one person calls 911 and gives the address; another fills a tub or large cooler with water and ice (time it); a third practices the rotating-towels method (soak towels in ice water, place on head, neck, armpits and groin, swap every minute). Write the plan on one card: who calls, where the tub and ice are, and “cool first, transport second.”

Tips

- Heart rate rises a little through a steady run in the heat even at the same pace (cardiovascular drift); compare 10-minute with 10-minute and 20-minute with 20-minute readings.
- If your area is cool this time of year, the test still shows fitness change at a fixed pace; save the heat plan for next summer.
- Acclimatization fades after a week or two away from heat, so after a vacation, ease back in.

Check your work

- ☐ I can describe the body’s heat-acclimatization changes and the 14-day guidelines.
- ☐ I can recognize heat exhaustion and heat stroke and explain “cool first, transport second.”
- ☐ I ran a fixed-pace test twice and wrote a heat plan, a heat-index rule and an emergency card.

FITNESS JOURNAL

1. Record both fixed-pace tests in a table: conditions, heat index, lap times, heart rates at 10 and 20 minutes, effort and sweat.
2. Copy your 14-day heat plan and your heat-index rule.
3. Make a three-column chart of heat cramps, heat exhaustion and exertional heat stroke: signs, what to do, and how serious.
4. Draw a timeline of the first 14 days of acclimatization and mark when plasma volume, heart rate, sweating and sweat saltiness change.

From history. Illness from the sun has been known for a long time: the Bible tells of a boy who cried “My head, my head” while out with the reapers at harvest (2 Kings 4:18-20), which many readers take to be sunstroke. Modern research on exercise in heat grew from studies of soldiers and desert workers in the 1940s, and the first detailed guidelines for athletes in the United States were written by sports-medicine groups from the 1970s onward.

COMMON MISTAKES

- Going all-out on the first hot day of preseason. The body needs about two weeks to adapt.
- Waiting for an ambulance before cooling a collapsed athlete. Cool first, transport second.
- Thinking heat illness can happen only on extremely hot days. Humidity, heavy equipment, poor fitness, illness and too little sleep raise the risk at lower temperatures.
- Ignoring confusion. Odd behavior or confusion in the heat is a sign of heat stroke, not just tiredness.

Make it a game • Fixed Pace Heat Test. Do a fixed-pace test: ten minutes of steady stepping, with your pulse before and after. Compare your numbers to a test a week later. Explain plasma volume and acclimatization over fourteen days. Your parent plays Korey Stringer's trainer and asks what you would do at the first sign of trouble. Beat your recovery.

Scripture. “The sun shall not smite thee by day, nor the moon by night.” (Psalm 121:6, KJV)

God keeps His people, and He gives wisdom to plan for the heat: rest, shade, water and a gradual start are part of that wisdom.

2.2 HYDRATION FOR ENDURANCE

EVENTS: TOO LITTLE AND TOO MUCH

OBJECTIVES

- Tell what the 2002 Boston Marathon study found about hyponatremia and what put runners at risk.
- Explain fluid and sodium balance, the kidney's limits and why drinking far more than you sweat is dangerous.
- Measure your sweat rate from a scale reading before and after exercise, recording only the fluid lost.
- Build a drinking plan for a long event that avoids both large fluid losses and fluid gains.

Warm-up. Jog easily for 3 minutes, then do 10 walking lunges, 10 squats, 10 leg swings on each leg and 3 short strides at a comfortable fast pace. Think about it: is there such a thing as drinking too much water? What would happen if you drank 2 cups of water every 15 minutes during a slow 5-hour walk?

WATCH

Water and Sodium Balance, Hypernatremia and Hyponatremia, Animation

Alila Medical Media · 5:33

<https://www.youtube.com/watch?v=72Ncvlr6GQk>

WHEN TO WATCH

After the “How your body works” paragraph. Focus on the first half, on water moving into and out of cells; the second half lists medical causes you do not need to memorize.

Note: A medical animation made for students in medicine and nursing, so it is detailed. The body figures are plain outlines. It shows how low blood sodium makes cells, including brain cells, swell.

BACKUP VIDEO

Jonathan on hyponatremia

The Real Science of Sport Podcast · 2:33

<https://www.youtube.com/watch?v=VU0n-LSG2Ms>

After the story, for a sports scientist’s short talk on how hyponatremia in runners came to be understood.

KEY TERMS

exercise-associated hyponatremia

A low sodium concentration in the blood (135 mmol/L or less) during or after exercise, usually from drinking more fluid than is lost; severe cases cause brain swelling.

osmosis

The movement of water across cell membranes toward the side with more dissolved particles. When blood sodium falls, water moves into cells and they swell.

sodium

The main electrolyte in the fluid outside cells, normally about 135–145 mmol per liter of blood; it controls where water goes in the body.

antidiuretic hormone (ADH)

A hormone that tells the kidneys to hold on to water. During long exercise it can stay switched on, so extra fluid is not passed as urine.

sweat rate

How much fluid you lose in sweat per hour, measured from the scale change before and after exercise plus fluid drunk, minus urine.

CORE IDEAS

The story. On April 15, 2002, Cynthia Lucero, a 28-year-old doctoral student in psychology who had just finished her dissertation, ran the Boston Marathon. Friends said she drank steadily at aid stations all along the course. Late in the race she began to falter, told a friend she felt “rubber-legged,” and collapsed. She died in the hospital; the medical examiner found that her blood sodium had fallen dangerously low and her brain had swollen. She had done what runners were often told to do: drink as much as you can. Her death helped change that advice.

How they figured it out. Doctors had first described this condition in ultramarathon runners in South Africa in the 1980s, but no one knew how common it was. At the same 2002 Boston Marathon, a team led by Christopher Almond of Children’s Hospital Boston weighed runners before the race, took a blood sample at the finish from 488 of them, and asked what they drank. Their results, published in the *New England Journal of Medicine* in 2005, were striking: 13 percent had hyponatremia (blood sodium of 135 mmol/L or less), and 0.6 percent had critical levels (120 or less). The strongest warning sign was **gaining weight** during the race, which means drinking more than was sweated out, along with finishing times over 4 hours. The kind of drink did not protect runners: sports drinks contain far less sodium than blood. Since then, sports-medicine groups have advised athletes to drink to a plan based on their own sweat rate, roughly matching but never exceeding their losses.

How your body works. Water follows sodium. Blood normally holds about 135–145 mmol of sodium per liter, and cells keep their size because the fluid inside and outside is balanced. Drink much more water than you lose, and the blood is diluted; by **osmosis** water moves into cells, which swell. Most organs can stretch, but the brain is enclosed in bone, so swelling brings headache, nausea, vomiting, confusion, seizures and, in the worst cases, death. Healthy kidneys can pass only about 0.8 to 1 liter (27–34 ounces) of urine an hour, and during long exercise **antidiuretic hormone** may stay high, so the kidneys pass even less. Slower runners, out on the course for many hours with time to drink at every station while sweating little, are at greatest

risk. The opposite problem matters too: losing a lot of fluid without replacing it reduces blood volume, raises heart rate and core temperature, and slows performance. The goal is the middle: finish a long event a little lighter than you started, never heavier. In a long event, salty snacks or a sports drink help replace some sodium, but no drink makes overdrinking safe.

Think it through. “Hast thou found honey? eat so much as is sufficient for thee” (Proverbs 25:16). Even good things become harmful in excess, and water is no exception. Thirst is a reliable guide for most people in most exercise, and a written plan based on your own sweat rate is better still for long events. A runner who is confused, vomiting or has a bad headache after a long race should not be given more plain water; he needs medical help right away.

Try it. This week you will measure your sweat rate. Worked example: before a 1-hour run the scale reads a certain number; afterward it reads 1.5 pounds less. You drank 12 ounces and did not use the bathroom. One pound of fluid is about 16 ounces, so 1.5 pounds is 24 ounces. $\text{Sweat lost} = 24 + 12 = 36$ ounces in 1 hour, a sweat rate of 36 ounces per hour (about 1.1 liters). Only the difference is recorded, as fluid lost; the scale numbers themselves are not written down.

PICTURE STUDY



Dorando Pietri Finishing the Marathon, London Olympic Games, Unknown photographer, July 24, 1908 · Photograph · Olympic Stadium, Shepherd's Bush, London
Image: [Wikimedia Commons](#), public domain

The marathon at the 1908 London Olympics was run on a hot, humid July afternoon. The Italian runner Dorando Pietri entered the stadium first but was so exhausted that he turned the wrong way and fell several times. Officials helped him across the line. Because he had been helped, he was disqualified, and the American Johnny Hayes was given the gold medal. Queen Alexandra, moved by his courage, presented Pietri with a gilded silver cup the next day.

Look closely

- Look at Pietri's face, arms and legs. What signs of exhaustion can you see?
- Find the two officials. What are they doing, and why did that cost Pietri the race?
- Look at the cloth on his head. Why might a runner wear it on a hot day?
- Look at the crowd. What does it tell you about how famous this moment became?

Talk about it

1. Runners in 1908 drank very little during races. How might too little fluid and the heat have added to Pietri's collapse?

2. Today a runner who collapses could be dehydrated, overheated or hyponatremic. Why must medical staff find out which before giving fluids?
3. What would a good drinking and pacing plan have looked like for Pietri's race?

Safety first. Do the sweat-rate test with a parent, at an easy to moderate effort, with water available; it is a measurement, not a test of how much you can lose. Never drink large amounts quickly or have drinking contests, and never try to gain or lose fluid on purpose. If you feel a pounding headache, nausea, confusion or swelling of the hands during or after long exercise, stop and get medical help.

ACTIVITY

My Sweat Rate and Drinking Plan

You will measure your own sweat rate on two sessions of the same workout, once drinking freely and once following a plan, and then write a drinking plan for a long event that keeps you near your starting fluid level.

You will need

- A bathroom scale on a hard, level floor
- A water bottle and a measuring cup (or a bottle with ounce marks)
- A stopwatch, a towel, and a safe 45- to 60-minute route or workout
- Your fitness journal with a table: date, conditions, minutes, scale change (lb), fluid drunk (oz), urine (oz or “none”), fluid lost (oz), sweat rate (oz/h)

Steps

1. **Before (Session 2).** Use the bathroom first. In the same light clothes you will wear afterward, step on the scale; your parent notes the number privately for the subtraction only. Fill your bottle and note how many ounces it holds.
2. **Exercise 45–60 minutes at a steady, moderate effort** (a run, a ride or a brisk walk-jog), drinking freely to thirst from your bottle only. Note the time, temperature and humidity.
3. **After.** Towel off all sweat, change into dry clothes of the same kind if yours are soaked, and step on the scale again. Your parent tells you only the difference. Measure what is left in the bottle to find how much you drank. If you used the bathroom, estimate the ounces.
4. **Calculate.** Fluid lost (oz) = scale drop (lb) $\times$ 16 + fluid drunk (oz) – urine (oz).
Sweat rate (oz/h) = fluid lost $\div$ hours. Convert to liters: ounces $\times$ 0.03 (about 30 mL per ounce). Record only the scale change and the fluid lost.
5. **Session 3: drink to a plan.** Repeat the same workout. This time, plan to drink about half to three-quarters of your sweat rate, spread evenly in small amounts every 15–20 minutes. Measure again. The goal is a small drop, near zero; a scale gain would mean you drank more than you lost.

6. **Write a plan for a 2-hour event** (a long run, a hike, a tournament day). Start hydrated (pale urine, about 16 ounces of fluid 2 hours before). During, drink about half to three-quarters of your hourly sweat rate, never more than your sweat rate, in small amounts. Add salty food or a sports drink after the first hour. Afterward, drink to thirst and eat a meal.
7. **Add warning signs to your plan:** for too little (strong thirst, dark urine, dizziness, rising heart rate) and too much (sloshing stomach, swollen fingers, headache, nausea, confusion, gaining weight).

Tips

- Sweat rates vary a great deal from person to person and with weather and effort; 16 to 48 ounces an hour is common for teenagers. That is why the plan must be yours.
- In a 5K or 10K, most runners need little or nothing to drink during the race if they start hydrated.
- Repeat the test in different weather; your sweat rate on a hot day can be double that on a cool one.

Check your work

- ☐ I can explain hyponatremia: cause, signs, risk factors and prevention.
- ☐ I measured my sweat rate twice and recorded only the fluid lost.
- ☐ I wrote a drinking plan for a 2-hour event that avoids both large losses and any gain.

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1. Copy both sweat-rate tables with every calculation shown, and compare the two scale changes.
2. Draw two cells: one in normal blood and one in diluted blood after overdrinking, with arrows showing which way water moves and why.
3. Write your 2-hour event drinking plan as a timeline, with ounces at each 15- or 20-minute mark.
4. Make a two-column chart of warning signs: too little fluid and too much fluid.

From history. Advice about drinking during exercise has swung back and forth. Early marathoners were often told to drink little or nothing. From the 1970s to the 1990s, many were told to drink as much as possible, even before thirst. After the hyponatremia studies of the 1980s to 2000s, sports-medicine groups revised their advice: drink to replace most of what you lose, guided by thirst and your own sweat rate, but do not drink beyond it.

COMMON MISTAKES

- Thinking “the more water, the better.” Drinking more than you sweat dilutes your blood sodium.
- Thinking sports drinks prevent hyponatremia. They contain much less sodium than blood; overdrinking any fluid is dangerous.
- Drinking at every aid station by habit in a slow, cool race. Drink to your plan and to thirst.
- Writing down your body weight. Only the change, as fluid lost, matters for this test.

Make it a game • Marathon Fluid Math. Given a runner's sweat rate, race length and sodium loss, calculate how much fluid is too little and too much. Your parent times you. Explain hyponatremia using sodium, osmosis and ADH. Tell the 2002 Boston Marathon findings. Argue why drinking beyond sweat loss is dangerous. Fewest math errors wins.

Scripture. “Hast thou found honey? eat so much as is sufficient for thee, lest thou be filled therewith, and vomit it.” (Proverbs 25:16, KJV)

Good gifts are meant to be taken in the right measure. Self-control applies even to water.

HYDRATION

Every August, high-school athletes across the country start practice in the hottest weeks of the year. The body can learn to handle heat, but it needs about two weeks to do it. In 2001 the Minnesota Vikings lineman Korey Stringer died of exertional heat stroke after a training-camp practice, and his death led to the Korey Stringer Institute at the University of Connecticut and to national guidelines that ease high-school athletes into hot-weather practice over 14 days. In this unit you will learn what changes inside the body during heat acclimatization, how to recognize heat illness, why the rule is “cool first, transport second,” and how to write a heat plan for your own sport.

Then you will look at the opposite danger. For years endurance athletes were told to drink as much as they could. After the 2002 Boston Marathon, a study of 488 finishers found that 13 percent had low blood sodium, mostly from drinking more than they sweated, and one young runner died of it. You will learn how fluid and sodium balance work, why both too little and too much fluid are harmful, and how to measure your own sweat rate to build a drinking plan for a long event.

PREREQUISITES

- Knows what water does in the body and the signs of dehydration (earlier grades)
- Knows that sweat contains sodium and other electrolytes, and how sweating cools the body
- Can take a pulse, use an effort rating and convert between ounces, cups and liters

MASTERY CHECKLIST

- ☐ I can describe the main body changes of heat acclimatization and why the first 14 days must be gradual.
- ☐ I can recognize heat exhaustion and exertional heat stroke and explain “cool first, transport second.”
- ☐ I can read a heat-index chart and write a heat plan for practice.
- ☐ I can explain exercise-associated hyponatremia: what causes it, its signs and how to prevent it.
- ☐ I can measure my sweat rate and build a drinking plan that avoids both too little and too much.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **Heat acclimatization (Korey Stringer Institute, University of Connecticut):** Free. The institute's plain summary of heat acclimatization for secondary-school athletes, with the 14-day guidelines. For Lesson 2.1.
- **A reusable water bottle with ounce or milliliter marks:** Makes the sweat-rate test and drinking plan in Lesson 2.2 easier. A measuring cup works just as well.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

2.1 Heat Acclimatization: The First Two Weeks

3 sessions of 45–50 minutes

2.2 Hydration for Endurance Events: Too Little and Too Much

3 sessions of 45–50 minutes

UNIT 2 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. 8 pts

Tell the story of Korey Stringer and name two changes in athlete heat safety that followed it.

2. 10 pts

List four body changes that happen during heat acclimatization, and say roughly how long acclimatization takes.

3. 8 pts

Summarize the 2009 high-school heat-acclimatization guidelines for days 1–5.

4. 10 pts

Compare heat exhaustion and exertional heat stroke. What is the first-aid rule for heat stroke, and why?

5. (6 pts)

Using the heat-index chart, the temperature is 90°F and the relative humidity 60 percent. What is the heat index, and why does humidity matter?

6. (8 pts)

What did Almond's study of the 2002 Boston Marathon find? Give the two percentages and the strongest risk factor.

7. (8 pts)

Explain why drinking far more than you sweat can cause brain swelling.

8. (10 pts)

A student's scale reading dropped 2 pounds during a 90-minute run. She drank 20 ounces and passed 4 ounces of urine. Find her fluid lost and her sweat rate in ounces per hour and liters per hour.

9. (8 pts)

Using the student in question 8, write a drinking plan for a 2-hour event in similar weather. How much should she drink per hour, and how often?

10. (6 pts)

A runner finishes a slow 5-hour marathon and the scale shows he is 2 pounds heavier than at the start. What does this suggest, and what should he watch for?

11. (8 pts)

In three to five sentences, explain how Proverbs 25:16 applies to drinking during long exercise.

12. (10 pts)

In four to six sentences, compare the dangers of the first hot week of preseason with the dangers of a long, slow endurance event. How would your planning differ?

ANSWER KEY

1. Stringer, a Minnesota Vikings lineman, collapsed after a hot practice at training camp in Mankato on July 31, 2001, and died of exertional heat stroke on August 1, age 27. Changes: the Korey Stringer Institute at UConn (2010); 14-day heat-acclimatization guidelines for high schools (2009) and state rules adopting them; emergency plans with cold-water immersion tubs at practices.
2. Any four: plasma volume increases; heart rate at the same pace falls; sweating starts sooner; sweat rate increases; sweat becomes less salty; core temperature stays lower; exercise feels easier. About 10–14 days, with most change in the first week.
3. No more than one practice a day, of up to 3 hours; intensity and equipment increased gradually (in football, helmets only on days 1–2, helmets and shoulder pads on days 3–5); no double-practice days until after day 5.
4. Heat exhaustion: weakness, dizziness, headache, nausea, heavy sweating, normal thinking; rest in shade, cool, sip fluids. Heat stroke: core temperature above about 104°F (40°C) with confusion, odd behavior or collapse; a life-threatening emergency. Rule: call 911 and cool first (cold-water immersion), transport second, because the time spent overheated decides survival; nearly everyone survives when cooled immediately.
5. About 100°F. High humidity slows sweat evaporation, so the body cools less effectively and feels hotter.
6. Of 488 runners tested at the finish, 13% had hyponatremia (sodium ≤ 135 mmol/L) and 0.6% had critical hyponatremia (≤ 120). The strongest risk factor was weight gain during the race (drinking more than was sweated); race times over 4 hours also raised the risk.
7. Extra water dilutes blood sodium; by osmosis water moves into cells, which swell. The brain is enclosed in bone, so swelling raises pressure, causing headache, nausea, confusion, seizures and possibly death. The kidneys can pass only about 0.8–1 L an hour, less when ADH stays high during exercise.
8. Fluid lost = $2 \times 16 + 20 - 4 = 48$ oz. Sweat rate = $48 \div 1.5 \text{ h} = 32 \text{ oz/h} \approx 32 \times 0.03 \approx 0.95 \text{ L/h}$ (about 1 liter per hour).
9. About half to three-quarters of 32 oz/h, so roughly 16–24 oz per hour, in small amounts (about 4–6 oz every 15 minutes or 5–8 oz every 20 minutes), never more than 32 oz per hour; start hydrated; add salty food or a sports drink after the first hour.

10. He drank more than he lost, about 32 oz extra, raising the risk of hyponatremia. Watch for headache, nausea, vomiting, swelling, confusion; he should not drink more plain water and should get medical help if symptoms appear.
11. Answers vary. Full credit for: even good things like water should be taken in the right measure; too little fluid harms performance and safety, but too much dilutes blood sodium and can be fatal; wisdom means drinking to thirst or a sweat-rate plan, never far beyond losses; self-control is part of caring for the body God gave.
12. Answers vary. Full credit for: early preseason risks exertional heat stroke and dehydration in unacclimatized athletes, so plan a gradual 14-day progression, cool times of day, shade, water breaks, a heat-index rule and a cold-water tub; a long slow event risks hyponatremia from overdrinking (and dehydration in heat), so plan from a measured sweat rate, drink no more than losses, add sodium in long events, and check that you do not finish heavier.

UNIT CHALLENGE: MY HEAT AND HYDRATION PLAN

Put together a personal heat and hydration plan for your sport or training. Include your 14-day heat-acclimatization schedule, your heat-index rule, your emergency card, both fixed-pace tests from Lesson 2.1, both sweat-rate tests from Lesson 2.2 with calculations, and your 2-hour event drinking plan. Finish with a page explaining the science behind each part of your plan.

LOOK FOR	WHAT IT MEANS
Sound heat plan	A day-by-day 14-day schedule that follows the guidelines, with times of day, breaks and a heat-index rule.
Emergency readiness	A clear emergency card and a family rehearsal of calling 911 and cold-water cooling, with the tub-filling time recorded.
Accurate measurements	Two sweat-rate tests with every calculation shown, recording only fluid lost.
Safe drinking plan	A timeline that replaces most but never more than measured losses, with warning signs for too little and too much.
Explanation	A page using the words acclimatization, plasma volume, heat stroke, hyponatremia and osmosis, judged on understanding and effort.

NUTRITION

What you eat matters, and so does when you eat it. In 1966 two Swedish physicians, Jonas Bergström and Eric Hultman, sat on opposite sides of a single exercise bicycle, each pedaling with one leg until it was exhausted, and then measured the sugar stored in their thigh muscles. Their experiment, and the studies that followed, showed that muscle glycogen is the fuel that hard training runs on, and that what you eat before and after training refills it. In this unit you will learn how glycogen, blood sugar and protein work around a training session, and you will plan, eat and test your own fueling timeline for a training day.

Then you will take on a skill every adult needs: feeding people well without spending too much. In 1890 the chemist Ellen Swallow Richards, the first woman to study at the Massachusetts Institute of Technology, opened the New England Kitchen in Boston to show that inexpensive ingredients could be made into nourishing, good-tasting food. You will learn to compare unit prices, plan a week of family dinners on a budget, shop with a list, cook in batches and store leftovers safely.

PREREQUISITES

- Knows the macronutrients and that carbohydrate and protein give about 4 calories per gram and fat about 9 (earlier grades)
- Can read a Nutrition Facts label for serving size, grams and added sugars
- Can use a knife and stove safely with a parent present

MASTERY CHECKLIST

- ☐ I can describe Bergström and Hultman's 1966 experiment and what it showed about muscle glycogen.
- ☐ I can plan what and when to eat before, during and after training, with grams of carbohydrate and protein from labels.
- ☐ I can test a fueling timeline and adjust it from how I felt and performed.
- ☐ I can calculate unit prices and cost per serving and use them to choose nutrient-dense foods on a budget.
- ☐ I can plan, shop for, cook and safely store a week of family meals.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“A Guide to Eating for Sports” (Nemours KidsHealth for Teens):** Free. A clear teen article on carbohydrate, protein, fluids, supplements and what to eat 3–4 hours before and after a game. Read it with Lesson 3.1.
- **A kitchen scale and storage containers with lids:** Optional. A scale makes gram estimates in Lesson 3.1 more accurate; shallow containers and masking-tape labels (dish and date) make safe leftovers easy in Lesson 3.2.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

3.1 Timing Meals for Training

3 sessions of 45–50 minutes

3.2 Cook for a Week on a Budget

3 sessions of 45–50 minutes

UNIT 3 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

Describe Bergström and Hultman’s 1966 experiment. What did they do, what did they measure and what did they find?

2. **8 pts**

What did the 1967 follow-up study show about muscle glycogen and endurance?

3. **8 pts**

Where is glycogen stored, roughly how much, and what job does each store do?

4. **8 pts**

Why is glycogen, not fat, the main limit on hard training, even though the body stores much more fat?

5. **8 pts**

Describe a good pre-exercise meal and a good recovery meal: timing and what each should contain.

6. **10 pts**

A pre-practice lunch has 1.5 cups cooked rice (45 g carbohydrate per cup), 1 banana (27 g carbohydrate) and 2 slices of bread (13 g carbohydrate each). How many grams of carbohydrate is that, and how many calories of food energy come from that carbohydrate?

7. **8 pts**

Build a recovery snack from real food with 20–30 g protein. Show the grams. (Milk 8 g per cup; egg 6 g; 3 oz chicken 25 g; 2 tbsp peanut butter 8 g.)

8. **6 pts**

Why should a teenage athlete get protein from food rather than protein powders or supplements?

9. **8 pts**

What did Ellen Swallow Richards set out to show with the New England Kitchen (1890), and how did she use science to do it?

10. **10 pts**

A 32-ounce bag of oats costs \$3.84 and an 18-ounce canister costs \$2.70. Find each unit price in cents per ounce. Which is the better buy, and how much would you save on 32 ounces?

11. **8 pts**

A pot of chili costs \$9.60 in ingredients and makes 8 servings. A box of frozen meals costs \$4.50 for 1 serving. Find the cost per serving of the chili and how much a family of 4 saves at one dinner by making chili.

12. **10 pts**

In four to six sentences, explain how planning meals for training and planning meals on a budget both reflect stewardship.

ANSWER KEY

1. They sat on opposite sides of one exercise bicycle and each pedaled with one leg to exhaustion while the other rested, then ate high-carbohydrate meals for several days and took muscle biopsies from both legs. The exercised leg's glycogen fell almost to zero, then rose to roughly double normal (supercompensation); the rested leg barely changed. The effect was local to the exercised muscle.
2. Starting muscle glycogen largely determined how long subjects could keep exercising hard; after high-carbohydrate meals they lasted roughly two to three times as long as after fat-and-protein meals.
3. In the muscles (roughly 300–500 g in an adult), used by that muscle for exercise; and in the liver (about 100 g), released to keep blood glucose steady for the brain and body.
4. Fat is broken down and used too slowly to supply energy fast enough for high-intensity work on its own; hard exercise relies heavily on carbohydrate (glycogen and glucose), and those stores are limited to a few hours.
5. Pre-exercise: about 3–4 hours before, carbohydrate-rich with some protein, lower in fat and fiber (plus a small snack 30–60 minutes before if needed). Recovery: within about 1–2 hours after, carbohydrate to refill glycogen and about 20–30 g protein for repair.
6. Rice $1.5 \times 45 = 67.5$ g; banana 27 g; bread $2 \times 13 = 26$ g. Total ≈ 120.5 g. Energy $\approx 120.5 \times 4 \approx 482$ calories.
7. Answers vary. Example: 2 cups milk (16 g) + 2 tbsp peanut butter (8 g) on bread = 24 g protein; or 3 eggs (18 g) + 1 cup milk (8 g) = 26 g.
8. Real food supplies plenty of protein along with other nutrients; supplements are not reviewed or approved by the FDA before they are sold, may contain things not on the label, and are unnecessary.
9. That inexpensive ingredients could be made into nourishing, good-tasting food that working families could afford. She analyzed the nutrients and cost of dishes, tested recipes for flavor, studied what people liked, and used cheaper ingredients that were often wasted.
10. $\$3.84 \div 32 = \0.12 per oz (12¢). $\$2.70 \div 18 = \0.15 per oz (15¢). The 32-oz bag is cheaper. On 32 oz: $32 \times (\$0.15 - \$0.12) = \$0.96$ saved.
11. Chili: $\$9.60 \div 8 = \1.20 per serving. Family of 4: chili $4 \times \$1.20 = \4.80 ; frozen meals $4 \times \$4.50 = \18.00 . Savings = $\$13.20$.

12. Answers vary. Full credit for: the body is God's gift and a temple to care for, so fueling it well for work and training is stewardship; money and food are also gifts to be used wisely; planning ahead (timelines, menus, lists) avoids waste and poor choices; low-cost nutrient-dense foods can serve both goals; thankfulness and self-control at the table (1 Corinthians 10:31) apply in both.

UNIT CHALLENGE: FUEL AND FEED: A WEEK OF PLANNED MEALS

Present a week of planned eating that serves both your training and your family's budget. Include your tested training-day fueling timeline from Lesson 3.1 with grams and results, and your budget week from Lesson 3.2: menu, shopping list with unit prices, estimated and actual cost, cost per serving, recipes cooked, family ratings, leftover labels and photos or drawings of the meals. Finish with a paragraph on what you would change next time.

LOOK FOR	WHAT IT MEANS
Tested fueling plan	A timeline with times, foods and grams of carbohydrate and protein, tested twice with honest ratings.
Balanced budget menu	Five dinners, each with protein, grain or starch, vegetables and fruit or milk, within the agreed budget.
Accurate math	Unit prices, totals and cost per serving calculated correctly, with work shown.
Cooking and food safety	At least two meals cooked with a parent's note on safe knife, stove and leftover handling.
Reflection	A paragraph on what worked and what to change, judged on effort and honesty.

3.1 TIMING MEALS FOR TRAINING

OBJECTIVES

- Describe Bergström and Hultman's 1966 one-legged cycling experiment and what it showed about muscle glycogen.
- Explain how glycogen, blood sugar and protein are used and restored around a training session.
- Plan meals and snacks before, during and after training, with grams of carbohydrate and protein worked out from labels.
- Test a fueling timeline on two training days and adjust it from your records.

Warm-up. Jog easily for 2 minutes, then do 10 squats, 10 push-ups at your level, 10 lunges on each leg and 20 seconds of fast feet. Think about it: what did you eat today, and when? If you had hard practice at 3:30 this afternoon, would that food still be helping you?

WATCH

Meet the Experts: Nutrition Tips for Young Athletes - Food, Supplements, Hydration

Arkansas Children's • 10:50

<https://www.youtube.com/watch?v=VQxUo9khoNM>

WHEN TO WATCH

After the “How your body works” paragraph. List what the dietitian recommends before and after games, and what she says about supplements.

Note: A board-certified sports dietitian from Arkansas Children's Hospital answers a football coach's questions about pre- and post-game foods, supplements and the best foods for athletes. You can stop after the “top 3 foods” section; the last seconds are a hospital reminder about other services.

BACKUP VIDEO

NFL Nutrition, Recovery & Performance Tips from Rams' Team Dietitian

Play Football • 4:41

<https://www.youtube.com/watch?v=fg0ElQKxBtg>

For a second view of fueling, sleep and pre- and post-training foods. Stop at 3:38.

KEY TERMS

glycogen

The stored form of glucose, kept in the muscles (for the muscles' own use) and in the liver (to keep blood sugar steady). It is the main fuel for hard exercise.

blood glucose

The sugar carried in the blood, fuel for the brain and working muscles, kept steady by the liver and by hormones such as insulin.

supercompensation

The rise of muscle glycogen above its usual level when a muscle that has been exercised hard is then fed plenty of carbohydrate.

pre-exercise meal

A meal eaten about 3–4 hours before training, rich in carbohydrate with some protein, and lower in fat and fiber so it digests comfortably.

recovery meal

A meal or snack eaten within about 1–2 hours after training, with carbohydrate to refill glycogen and protein (about 20–30 grams) to help repair muscle.

CORE IDEAS

The story. In the early 1960s Jonas Bergström, a Swedish physician, revived an old idea: a hollow needle that could take a tiny sample of muscle, about the size of a grain of rice, from a living person. With it he and his colleague Eric Hultman could finally see how much glycogen was inside a working muscle. In 1966 they tried an experiment on themselves. They sat on opposite sides of one stationary bicycle, and each pedaled with only one leg until that leg was exhausted, while his other leg rested. Then for several days they ate meals very high in carbohydrate, and took muscle samples from both legs.

How they figured it out. The exercised leg's glycogen had fallen almost to nothing, but over the next days it climbed back to roughly double its usual level, while the rested leg barely changed. The effect was local: something about hard exercise made that muscle store extra fuel. They published the result in *Nature* in 1966. The next year Bergström, Hultman and their colleagues showed that the amount of glycogen in the muscles before exercise largely decided how long a person could keep cycling

hard: after days of high-carbohydrate meals, subjects lasted roughly two to three times as long as after days of fat and protein meals. These studies are the foundation of today's advice about eating before and after training.

How your body works. An adult stores roughly 300 to 500 grams of glycogen in the muscles and about 100 grams in the liver. At 4 calories per gram, that is a few hours' fuel for hard exercise, which is why glycogen, not fat, limits hard training: fat stores are large, but fat is broken down too slowly to power high-intensity work alone. Overnight the liver uses much of its glycogen to keep blood sugar steady for the brain, so breakfast matters. A **pre-exercise meal** 3–4 hours before training should be rich in carbohydrate (rice, pasta, potatoes, bread, oats, fruit), with some protein and less fat and fiber, which digest slowly. A small snack 30–60 minutes before (a banana, crackers, a slice of toast) tops up blood sugar. In sessions longer than about 60–90 minutes, 30–60 grams of carbohydrate an hour helps. Afterward, muscles refill glycogen fastest in the first hours, and protein supplies amino acids for repair, so a **recovery meal** within about 1–2 hours should include carbohydrate and roughly 20–30 grams of protein. Real food does all of this; a teenage athlete does not need protein powders or supplements, which are not checked by the Food and Drug Administration before they are sold.

Think it through. Fueling is about giving the body what it needs for the work God has given it, not about restriction or rules for their own sake. A meal schedule should fit your family's table, too: often the best recovery meal is simply family dinner. Use labels to estimate grams. Worked example: a pre-practice lunch of 2 cups of cooked rice (about 45 g carbohydrate per cup = 90 g), 3 ounces of chicken (about 25 g protein) and an apple (about 25 g carbohydrate) gives about 115 g of carbohydrate and 25 g of protein. A recovery snack of 2 cups of milk (about 8 g protein and 12 g carbohydrate per cup) and a peanut butter sandwich (about 8 g protein from 2 tablespoons and 25 g carbohydrate from the bread) gives about 24 g protein and 49 g carbohydrate.

Try it. This week you will plan a fueling timeline around a fixed workout, eat it and test it, then change one thing and test it again.

PICTURE STUDY



The Dinner Horn (Blowing the Horn at Seaside), Winslow Homer, 1870 · Oil on canvas · National Gallery of Art, Washington, D.C.

Image: [Wikimedia Commons](#), public domain

In the 1870s Winslow Homer painted country life in New England and New York. On many farms, the midday meal was the biggest of the day, and someone at the house blew a horn to call the workers in from the fields. Here a young woman calls the haymakers to dinner, the meal that would fuel the rest of their afternoon's work.

Look closely

- Find the workers far off in the field. What work are they doing, and how long might they have been at it?
- Look at the woman's posture. How hard is she blowing the horn? How far must the sound carry?
- Find the milk can and buckets by the house. What foods might the farm have produced for this meal?
- Look at the light and the shadows. About what time of day is it?

Talk about it

1. The haymakers ate their big meal at midday and worked again in the afternoon. How is that like a pre-exercise meal 3–4 hours before practice?

2. What would a good meal for these workers include, using the farm's foods, to refill their energy and repair their muscles?
3. How does a regular mealtime, called by a horn, help hard-working people stay strong?

Safety first. Check for food allergies before planning or tasting, and follow any eating plan your doctor has set; a parent supervises knives and the stove. Do the test workout at a steady, safe effort with water, warmed up and cooled down, and do not skip meals to see what happens; if you feel shaky, dizzy or faint during exercise, stop, sit down, eat a small carbohydrate snack and tell an adult.

ACTIVITY

My Training-Day Fueling Timeline

You will plan exactly what and when to eat around a set workout, eat it, train, and record how you felt and performed. On the second day you will change one thing in the plan and see what happens. The goal is a timeline that leaves you strong, comfortable and recovered.

You will need

- Food labels, measuring cups and a kitchen scale (optional)
- A clock or phone timer
- A repeatable workout: for example, a 10-minute warm-up, then 6×2 minutes of hard running with 2 minutes of easy jogging between, and a 5-minute cool-down, on a measured loop
- Your fitness journal with a fueling table: time, food, grams of carbohydrate, grams of protein, and comfort and energy ratings

Steps

1. **Plan the timeline (Session 1 or the night before).** Choose your workout time. Plan a pre-exercise meal 3–4 hours before (carbohydrate-rich, some protein, lower fat and fiber), a small snack 30–60 minutes before, water through the day, and a recovery meal or snack within 1 hour after. Write each food with its grams of carbohydrate and protein from labels.
2. **Check the numbers.** Aim for a pre-exercise meal with plenty of carbohydrate (often 60–120 g for a teenage athlete) and a recovery meal with 20–30 g of protein and carbohydrate. Add up your totals and show the arithmetic.
3. **Session 2: eat and train.** Eat as planned and note the actual times. Before the workout, rate energy (1–10) and stomach comfort (1 = uncomfortable, 5 = comfortable). Do the workout, recording the distance or laps covered in each hard 2-minute interval.
4. **After the workout.** Rate energy and comfort again and note when you ate your recovery food. That evening and the next morning, rate how recovered your legs feel (1–5).

5. **Change one thing.** Choose one change to test: move the pre-exercise meal earlier or later, try a different snack, add a recovery snack sooner, or (for a long session) add carbohydrate during it. Write a prediction.
6. **Session 3: repeat.** Do the same workout at the same time with the changed timeline. Record the same ratings and interval distances.
7. **Compare.** Make a table of both days: meal timing, grams, energy, comfort, interval distances and next-day recovery. Write which timeline worked better and why you think so.

Tips

- Never try a new food or timing on a game or race day. Test it in training first.
- If your stomach is upset during exercise, try a smaller pre-exercise meal, lower in fat and fiber, or eat it earlier.
- Family dinner after evening practice is often the perfect recovery meal; just make sure it has carbohydrate and protein.

Check your work

- ☐ I can explain what Bergström and Hultman showed about glycogen and why timing matters.
- ☐ I planned a fueling timeline with grams of carbohydrate and protein worked out from labels.
- ☐ I tested it twice, changed one thing and compared the results honestly.

FITNESS JOURNAL

1. Copy both fueling timelines with every food, time and gram total, and your energy, comfort and recovery ratings.
2. Draw a graph of muscle glycogen through a training day: a fall during the workout and a rise after the recovery meal, labeling meals and the workout.
3. List ten real foods you like, sorted into good pre-exercise foods, good snacks and good recovery foods, with grams of carbohydrate and protein for a serving of each.
4. Write what you would eat the day before, the morning of and after a race or big game.

From history. The muscle biopsy needle Bergström used was based on a design first made in the 1860s by the French scientist Guillaume Duchenne. Bergström's version, developed in Stockholm, made it possible to study human muscle directly, and it has been used ever since to learn about fiber types, glycogen and how training changes muscle.

COMMON MISTAKES

- Skipping breakfast or lunch before afternoon practice. The liver's glycogen is low and there is nothing to refill it.
- Eating a large, high-fat meal right before training. It digests slowly and can upset the stomach.
- Waiting hours to eat after hard training. Glycogen refills fastest in the first hours.
- Thinking protein powders or supplements are necessary. Real food supplies plenty, and supplements are not checked by the FDA before sale.

Make it a game • Fuel Timeline Builder. Plan a training day on a timeline from wake-up to recovery meal. Place each meal and explain what glycogen and blood glucose are doing. Tell Bergstrom and Hultman's one-legged cycling story. Your parent plays the athlete and challenges the timing. Defend every slot in under sixty seconds.

3.2 COOK FOR A WEEK ON A BUDGET

OBJECTIVES

- Tell how Ellen Swallow Richards and the New England Kitchen showed that inexpensive food could be nourishing and good.
- Calculate unit prices and cost per serving, and choose nutrient-dense foods that give the most nutrition for the money.
- Plan a week of family dinners within a budget, with a shopping list and a batch-cooking plan.
- Cook at least two of the meals and store leftovers safely.

Warm-up. March briskly for 1 minute, then do 10 squats, 10 wall or incline push-ups, 10 reverse lunges on each leg and a 30-second plank. Think about it: if your family had a set amount of money for groceries this week, which foods would give the most good food for the money? How would you find out?

WATCH

How Can I Save Money on Groceries?

Two Cents • 6:31

https://www.youtube.com/watch?v=1VAZmcJ6_50

WHEN TO WATCH

After the “How your body works” paragraph, before you write your meal plan and shopping list. Note each tip you can use this week.

Note: From PBS Digital Studios’ personal-finance series, hosted by a certified financial planner. It explains how supermarkets are laid out to make shoppers spend more, and how a meal plan, a list, unit prices and cooking at home beat those tricks. A few seconds of old film and movie-style clips open the video.

BACKUP VIDEO

Essential Life Skills for Teens | Grocery Shopping: A Guide for Teens

Goffstown Public Library • 5:08

<https://www.youtube.com/watch?v=VnQLpVRhwqg>

Before you write your shopping list.

KEY TERMS

unit price

The price per unit of measure (per ounce, pound, liter or count), found by dividing the total price by the size. It lets you compare packages of different sizes.

nutrient-dense food

A food that gives a lot of vitamins, minerals, protein or fiber for its calories, such as beans, eggs, vegetables, fruit, whole grains and milk.

pantry staple

A low-cost, long-keeping food used in many meals, such as rice, oats, dried beans, flour, canned tomatoes and frozen vegetables.

cost per serving

The cost of one portion of food, found by dividing the price of the package by the number of servings it gives.

batch cooking

Cooking a large amount of a dish at once to eat over several meals, saving time and money.

CORE IDEAS

The story. Ellen Swallow Richards grew up in Massachusetts and in 1870 became the first woman admitted to the Massachusetts Institute of Technology, where she studied chemistry and later taught. She tested water, air and food, and she was troubled that many working families in Boston spent much of their wages on food that gave them little nourishment. On January 24, 1890, with Mary Hinman Abel, she opened the **New England Kitchen** on Pleasant Street in Boston. It cooked and sold soups, stews, porridges and breads made from inexpensive ingredients, at prices working people could afford.

How they figured it out. Richards treated the kitchen as a laboratory. She used chemistry to work out the protein, fat and carbohydrate in each dish and its cost, tested recipes for flavor as well as nutrition, studied what families actually liked to eat, and found uses for cheaper cuts and ingredients that were often thrown away. In 1893 she and Abel ran the Rumford Kitchen at the World's Columbian Exposition in

Chicago, where visitors could buy meals labeled with their nutritional values and cost. In 1894 the New England Kitchen began preparing lunches for Boston's public high schools, one of the early school-lunch programs in America. Richards went on to help found the field of home economics.

How your body works. Your body needs the same nutrients whether a meal is expensive or cheap: carbohydrate for energy, protein for growth and repair, fats, vitamins, minerals and fiber. Many of the most **nutrient-dense** foods are also among the cheapest: dried beans and lentils (protein, fiber, iron), eggs, oats, rice, potatoes, carrots, cabbage, bananas, milk, canned fish and frozen vegetables (frozen soon after harvest, they keep their vitamins well). To compare, use the **unit price**. Worked example with sample prices: a 2-pound bag of dried pinto beans for \$2.50 costs \$1.25 per pound and makes about 24 half-cup servings of cooked beans, about \$0.10 a serving; a 15-ounce can for \$1.09 gives about 3.5 servings, about \$0.31 a serving. Canned is more convenient, dried is about a third of the cost; both are good food.

Think it through. Proverbs 31 praises the woman who “riseth also while it is yet night, and giveth meat to her household” (Proverbs 31:15): planning and cooking for others is honorable work. A plan saves money: shop from a list, build meals around a few staples, cook big batches and use leftovers. Keep food safe: refrigerate leftovers within 2 hours (1 hour on a day above 90°F), eat them within 3 to 4 days, and reheat them to 165°F.

Try it. This week you will plan five family dinners within a budget you set with your parent, price them, shop, and cook at least two of them, one as a batch to provide leftovers.

PICTURE STUDY



The Return from Market (La Pourvoyeuse), Jean-Baptiste-Siméon Chardin, 1739 · Oil on canvas · Musée du Louvre, Paris (Chardin painted several versions)

Image: [Wikimedia Commons](#), public domain

Jean-Baptiste-Siméon Chardin painted the quiet work of Parisian households: cooks scrubbing pots, children at their lessons, mothers saying grace. Here a servant has just come back from market with bread and a bag of provisions and pauses for breath. Chardin made several versions of this painting; one hangs in the Louvre.

Look closely

- Find the two loaves of bread. Why might bread be one of the main things she bought?
- Look at the heavy bag in her hand. What might be in it? How far might she have carried it?
- Look at her face and posture. What does she seem to be thinking about?
- Find the woman in the doorway behind her. What might she be doing?

Talk about it

1. This servant had to feed a household with the money she was given. What would she need to know to do it well?
2. Bread was the main food of most French families in 1739. What low-cost staple foods form the base of your family's meals?

3. How is carrying the week's food home like a strength exercise? Which of the five movement patterns does it use?

Safety first. A parent supervises all knife and stove work: cut on a stable board, curl your fingertips away from the blade, turn pot handles inward and use oven mitts. Wash your hands before cooking and after handling raw meat or eggs, keep raw meat away from ready-to-eat foods, cook ground meat to 160°F and poultry to 165°F, and check for food allergies before you plan the menu.

ACTIVITY

The Budget Week

You will plan, price, shop for and cook a week of family dinners, the way Ellen Swallow Richards planned meals in the New England Kitchen: nourishing, good to eat and within a budget. You will cook at least two of them yourself.

You will need

- A budget for five dinners, set with your parent
- Store flyers, a store website or a visit to the store, and a calculator
- Your family's pantry and refrigerator (take an inventory first)
- Ordinary kitchen equipment: a large pot, a sheet pan, a cutting board, a knife, measuring cups and storage containers with lids
- Your fitness journal

Steps

1. **Take a pantry inventory (Session 1 or 2).** List the staples you already have. Planning around them saves money.
2. **Plan five dinners.** Each should include a protein food, a grain or starchy vegetable, at least one vegetable, and fruit or milk on the side. Use at least two low-cost proteins (beans, lentils, eggs, chicken thighs, canned tuna, ground turkey) and plan one large batch dish (chili, bean soup, a pasta bake) that gives leftovers for a second meal or lunches.
3. **Write the shopping list by store section** (produce, dairy, meat, grains, canned and frozen), with the amount of each food you need.
4. **Price it.** For each item, write the price and unit price. For at least three items, compare two sizes or forms (dried and canned beans, store brand and name brand, fresh and frozen vegetables) and choose by unit price and use.
5. **Total and adjust.** Add the cost of the list. If it is over budget, swap ingredients (for example, half the meat replaced by beans in chili) and recalculate. Then figure the cost per serving of each dinner: $\text{total ingredient cost} \div \text{number of servings}$.

6. **Shop with your parent** and record the actual total. How close was your estimate?
7. **Session 2: cook the batch dish.** Follow the recipe, measuring carefully. Serve the family, then cool and refrigerate the leftovers within 2 hours in shallow, labeled containers (dish and date).
8. **Session 3: cook a second dinner,** such as a sheet-pan meal of chicken thighs, potatoes and carrots, or eggs with vegetables and toast. Ask the family to rate each meal 1–5 and write down one improvement.

Tips

- Frozen vegetables are often cheaper than fresh, just as nutritious, and never go bad in the crisper drawer.
- Store brands usually cost less and are often made to the same standards.
- Cook once, eat twice: a pot of chili on Monday can become burritos on Wednesday.

Check your work

- ☐ I can explain what Ellen Swallow Richards’s New England Kitchen set out to show.
- ☐ I can calculate unit price and cost per serving and use them to choose foods.
- ☐ I planned five budget dinners, shopped, cooked two and stored leftovers safely.

FITNESS JOURNAL

1. Copy your five-dinner plan, shopping list with unit prices, total, budget and actual cost.
2. Show three unit-price comparisons with the arithmetic, and the cost per serving of each dinner.
3. Write the recipes you cooked, with notes on what went well, the family’s ratings and one change.
4. Make a leftovers label and a one-week chart of when each leftover must be eaten.

From history. Ellen Swallow Richards (1842–1911) earned a bachelor’s degree from MIT in 1873, the first woman to do so, and later ran MIT’s Woman’s Laboratory, which taught chemistry to women. She carried out a famous survey of the water quality of Massachusetts, which led to the first state water-quality standards in the United States.

COMMON MISTAKES

- Comparing package prices instead of unit prices. A bigger package is not always cheaper per ounce.
- Shopping without a list. Unplanned buys add up quickly.
- Thinking healthy eating must be expensive. Beans, eggs, oats, rice, potatoes, cabbage, carrots, bananas and frozen vegetables are low-cost and nutrient-dense.
- Leaving leftovers out on the counter for hours. Refrigerate within 2 hours and eat within 3 to 4 days.

Make it a game • Budget Week Auction. Gather three food packages. Calculate unit price and cost per serving in ninety seconds. Fastest right answer scores. Then build a budget week menu with nutrient-dense foods. Tell Ellen Swallow Richards's story. Your parent audits your plan and tries to beat your cost per serving. Lowest cost with best nutrition wins.

Scripture. “She riseth also while it is yet night, and giveth meat to her household, and a portion to her maidens.” (Proverbs 31:15, KJV)

Planning and preparing food for a household is honorable work. Doing it wisely, within the means God provides, is part of stewardship.

NUTRITION

What you eat matters, and so does when you eat it. In 1966 two Swedish physicians, Jonas Bergström and Eric Hultman, sat on opposite sides of a single exercise bicycle, each pedaling with one leg until it was exhausted, and then measured the sugar stored in their thigh muscles. Their experiment, and the studies that followed, showed that muscle glycogen is the fuel that hard training runs on, and that what you eat before and after training refills it. In this unit you will learn how glycogen, blood sugar and protein work around a training session, and you will plan, eat and test your own fueling timeline for a training day.

Then you will take on a skill every adult needs: feeding people well without spending too much. In 1890 the chemist Ellen Swallow Richards, the first woman to study at the Massachusetts Institute of Technology, opened the New England Kitchen in Boston to show that inexpensive ingredients could be made into nourishing, good-tasting food. You will learn to compare unit prices, plan a week of family dinners on a budget, shop with a list, cook in batches and store leftovers safely.

PREREQUISITES

- Knows the macronutrients and that carbohydrate and protein give about 4 calories per gram and fat about 9 (earlier grades)
- Can read a Nutrition Facts label for serving size, grams and added sugars
- Can use a knife and stove safely with a parent present

MASTERY CHECKLIST

- ☐ I can describe Bergström and Hultman's 1966 experiment and what it showed about muscle glycogen.
- ☐ I can plan what and when to eat before, during and after training, with grams of carbohydrate and protein from labels.
- ☐ I can test a fueling timeline and adjust it from how I felt and performed.
- ☐ I can calculate unit prices and cost per serving and use them to choose nutrient-dense foods on a budget.
- ☐ I can plan, shop for, cook and safely store a week of family meals.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“A Guide to Eating for Sports” (Nemours KidsHealth for Teens):** Free. A clear teen article on carbohydrate, protein, fluids, supplements and what to eat 3–4 hours before and after a game. Read it with Lesson 3.1.
- **A kitchen scale and storage containers with lids:** Optional. A scale makes gram estimates in Lesson 3.1 more accurate; shallow containers and masking-tape labels (dish and date) make safe leftovers easy in Lesson 3.2.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

3.1 Timing Meals for Training

3 sessions of 45–50 minutes

3.2 Cook for a Week on a Budget

3 sessions of 45–50 minutes

UNIT 3 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

Describe Bergström and Hultman’s 1966 experiment. What did they do, what did they measure and what did they find?

2. **8 pts**

What did the 1967 follow-up study show about muscle glycogen and endurance?

3. **8 pts**

Where is glycogen stored, roughly how much, and what job does each store do?

4. **8 pts**

Why is glycogen, not fat, the main limit on hard training, even though the body stores much more fat?

5. **8 pts**

Describe a good pre-exercise meal and a good recovery meal: timing and what each should contain.

6. **10 pts**

A pre-practice lunch has 1.5 cups cooked rice (45 g carbohydrate per cup), 1 banana (27 g carbohydrate) and 2 slices of bread (13 g carbohydrate each). How many grams of carbohydrate is that, and how many calories of food energy come from that carbohydrate?

7. **8 pts**

Build a recovery snack from real food with 20–30 g protein. Show the grams. (Milk 8 g per cup; egg 6 g; 3 oz chicken 25 g; 2 tbsp peanut butter 8 g.)

8. **6 pts**

Why should a teenage athlete get protein from food rather than protein powders or supplements?

9. **8 pts**

What did Ellen Swallow Richards set out to show with the New England Kitchen (1890), and how did she use science to do it?

10. **10 pts**

A 32-ounce bag of oats costs \$3.84 and an 18-ounce canister costs \$2.70. Find each unit price in cents per ounce. Which is the better buy, and how much would you save on 32 ounces?

11. **8 pts**

A pot of chili costs \$9.60 in ingredients and makes 8 servings. A box of frozen meals costs \$4.50 for 1 serving. Find the cost per serving of the chili and how much a family of 4 saves at one dinner by making chili.

12. **10 pts**

In four to six sentences, explain how planning meals for training and planning meals on a budget both reflect stewardship.

ANSWER KEY

1. They sat on opposite sides of one exercise bicycle and each pedaled with one leg to exhaustion while the other rested, then ate high-carbohydrate meals for several days and took muscle biopsies from both legs. The exercised leg's glycogen fell almost to zero, then rose to roughly double normal (supercompensation); the rested leg barely changed. The effect was local to the exercised muscle.
2. Starting muscle glycogen largely determined how long subjects could keep exercising hard; after high-carbohydrate meals they lasted roughly two to three times as long as after fat-and-protein meals.
3. In the muscles (roughly 300–500 g in an adult), used by that muscle for exercise; and in the liver (about 100 g), released to keep blood glucose steady for the brain and body.
4. Fat is broken down and used too slowly to supply energy fast enough for high-intensity work on its own; hard exercise relies heavily on carbohydrate (glycogen and glucose), and those stores are limited to a few hours.
5. Pre-exercise: about 3–4 hours before, carbohydrate-rich with some protein, lower in fat and fiber (plus a small snack 30–60 minutes before if needed). Recovery: within about 1–2 hours after, carbohydrate to refill glycogen and about 20–30 g protein for repair.
6. Rice $1.5 \times 45 = 67.5$ g; banana 27 g; bread $2 \times 13 = 26$ g. Total ≈ 120.5 g. Energy $\approx 120.5 \times 4 \approx 482$ calories.
7. Answers vary. Example: 2 cups milk (16 g) + 2 tbsp peanut butter (8 g) on bread = 24 g protein; or 3 eggs (18 g) + 1 cup milk (8 g) = 26 g.
8. Real food supplies plenty of protein along with other nutrients; supplements are not reviewed or approved by the FDA before they are sold, may contain things not on the label, and are unnecessary.
9. That inexpensive ingredients could be made into nourishing, good-tasting food that working families could afford. She analyzed the nutrients and cost of dishes, tested recipes for flavor, studied what people liked, and used cheaper ingredients that were often wasted.
10. $\$3.84 \div 32 = \0.12 per oz (12¢). $\$2.70 \div 18 = \0.15 per oz (15¢). The 32-oz bag is cheaper. On 32 oz: $32 \times (\$0.15 - \$0.12) = \$0.96$ saved.
11. Chili: $\$9.60 \div 8 = \1.20 per serving. Family of 4: chili $4 \times \$1.20 = \4.80 ; frozen meals $4 \times \$4.50 = \18.00 . Savings = $\$13.20$.

12. Answers vary. Full credit for: the body is God's gift and a temple to care for, so fueling it well for work and training is stewardship; money and food are also gifts to be used wisely; planning ahead (timelines, menus, lists) avoids waste and poor choices; low-cost nutrient-dense foods can serve both goals; thankfulness and self-control at the table (1 Corinthians 10:31) apply in both.

UNIT CHALLENGE: FUEL AND FEED: A WEEK OF PLANNED MEALS

Present a week of planned eating that serves both your training and your family's budget. Include your tested training-day fueling timeline from Lesson 3.1 with grams and results, and your budget week from Lesson 3.2: menu, shopping list with unit prices, estimated and actual cost, cost per serving, recipes cooked, family ratings, leftover labels and photos or drawings of the meals. Finish with a paragraph on what you would change next time.

LOOK FOR	WHAT IT MEANS
Tested fueling plan	A timeline with times, foods and grams of carbohydrate and protein, tested twice with honest ratings.
Balanced budget menu	Five dinners, each with protein, grain or starch, vegetables and fruit or milk, within the agreed budget.
Accurate math	Unit prices, totals and cost per serving calculated correctly, with work shown.
Cooking and food safety	At least two meals cooked with a parent's note on safe knife, stove and leftover handling.
Reflection	A paragraph on what worked and what to change, judged on effort and honesty.

UNIT 4

STRENGTH

Strength is the ability to produce force. Power is the ability to produce it fast, and nearly every sport depends on it: the jump for a rebound, the first steps of a sprint, the swing of a bat. In the 1960s the Soviet sports scientist Yuri Verkhoshansky developed what he called the “shock method,” jumps in which the muscles are stretched hard and then contract at once, and in 1975 the American coach Fred Wilt gave such training the name “plyometrics.” Long before, Ray Ewry, a boy who had polio, built his legs with jumping exercises and won eight Olympic gold medals in the standing jumps. In this unit you will learn how the stretch-shortening cycle works, why landing well comes first, and how to train power with low volume and good form, measuring your jump height with a little physics.

Then you will design strength training for your own sport. In 1969 the University of Nebraska hired Boyd Epley, a former pole vaulter, as one of the first full-time strength coaches in college sports, and in 1978 he founded the National Strength and Conditioning Association. Coaches like him taught that a good program begins with a needs analysis: what does this sport demand, and what does this athlete need? You will analyze your sport, choose exercises from the five main movement patterns (squat, hinge, push, pull and carry), learn them with light free weights or household loads under a knowledgeable adult’s eye, and estimate your strength safely from a set of 8–10 reps, never from a maximum lift.

PREREQUISITES

- Knows good form for the squat, hinge, push-up, row and lunge with body weight (earlier grades)
- Knows sets, reps, rest and progressive overload, and the slow- and fast-twitch fibers
- Can land softly from a jump with knees over toes (Lesson 1.2)

MASTERY CHECKLIST

- ☐ I can explain power, the stretch-shortening cycle and how Verkhoshansky's shock method led to plyometrics.
- ☐ I can land safely and do a low-volume plyometric session, counting foot contacts.
- ☐ I can calculate jump height from hang time and measure a vertical jump.
- ☐ I can do a needs analysis for a sport and choose exercises from the five movement patterns.
- ☐ I can train with light free weights safely, with a spotter for pressing, and estimate strength from a set of 8–10 reps instead of a maximum lift.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“Strength Training” (Nemours KidsHealth for Teens)**: Free. A teen article on how strength training works, supervision, form and safety. Read it with Lesson 4.2.
- **Light dumbbells or a kettlebell**: Optional, for Lesson 4.2, used only with a knowledgeable adult present. Water jugs, a backpack with books and push-ups do the same jobs.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

4.1 Power and Plyometrics

3 sessions of 45–50 minutes

4.2 Strength for Your Sport

3 sessions of 45–50 minutes

UNIT 4 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

Who was Ray Ewry, and how does his story connect to jump training?

2. **8 pts**

What was Yuri Verkhoshansky's shock method, and who coined the word "plyometrics"?

3. **10 pts**

Name and describe the three phases of the stretch-shortening cycle, and explain why a short middle phase gives a higher jump.

4. **10 pts**

A jumper's hang time is 0.60 seconds. Using $h = g t^2 \div 8$ with $g = 9.81 \text{ m/s}^2$, find the jump height in meters and in inches ($1 \text{ m} \approx 39.4 \text{ in}$).

5. **8 pts**

List four safety rules for plyometric training in this course.

6. **8 pts**

A session has snap-downs 2×6 , squat jumps 2×5 , broad jumps 2×4 and line hops 4×10 . How many foot contacts is that? Is it suitable for a beginner?

7. **8 pts**

Who was Boyd Epley, and why does his work matter for high-school athletes?

8. **8 pts**

What are the two parts of a needs analysis? Give three questions about the sport.

9. **8 pts**

Name the five movement patterns, and give one sport action and one exercise for each.

10. **10 pts**

A student does 9 good reps of a dumbbell Romanian deadlift with a 35-pound dumbbell. Use estimated max = load $\times$ (1 + reps $\div$ 30). Four weeks later she does 12 reps with the same dumbbell. Find both estimates and the percent increase.

11. **6 pts**

When is a spotter required in this course, and what does the spotter do?

12. **8 pts**

In three to five sentences, explain why this course estimates strength from a set of 8–10 reps instead of testing a one-repetition maximum.

ANSWER KEY

1. An American jumper (born 1873) who had polio as a boy and built up his legs with jumping exercises; at Purdue he became a champion and won eight Olympic gold medals in the standing jumps (1900, 1904, 1908). Repeated jumping training built his leg power.
2. A Soviet training method of the 1960s using depth jumps: dropping from a box, landing and immediately rebounding, so the muscles are stretched hard and then contract at once; intended for well-prepared athletes in small amounts. The American coach Fred Wilt coined “plyometrics” in 1975.
3. Eccentric: muscles and tendons stretch while braking, storing elastic energy and triggering the stretch reflex. Amortization: the brief turn-around. Concentric: the muscles shorten powerfully for takeoff. A short amortization phase uses the stored elastic energy and reflex before they are lost as heat.
4. $h = 9.81 \times 0.36 \div 8 = 3.5316 \div 8 \approx 0.44$ m. In inches: $0.44 \times 39.4 \approx 17.4$ in.
5. Any four: knowledgeable adult present; full warm-up; grass or firm non-slip floor and good shoes; learn landings first; low volume (about 50–80 contacts for beginners); full rest between sets; at least 48 hours between sessions; stop when landings get loud or knees cave; no depth jumps or box drops; stop at sharp or joint pain.
6. $12 + 10 + 8 + 40 = 70$ contacts. Yes; it is within the beginner range of about 50–80.
7. A former Nebraska pole vaulter hired in 1969 as one of the first full-time college strength coaches; he founded the NSCA in 1978. He helped establish strength and conditioning as a profession and showed that well-planned strength training makes athletes faster, more powerful and less injured; the NSCA now sets standards and supports safe youth training.
8. Evaluation of the sport and assessment of the athlete. Sport questions: What movements does it use? Which energy systems? Where do injuries most often occur? (Also: what is the season?)
9. Examples: squat (landing a jump; goblet squat); hinge (sprint start or tackle; Romanian deadlift); push (blocking or throwing; push-up or press); pull (swimming stroke or climbing; row); carry (holding steady against contact; farmer’s carry).
10. Before: $35 \times (1 + 9/30) = 35 \times 1.30 = 45.5$ lb. After: $35 \times (1 + 12/30) = 35 \times 1.40 = 49$ lb. Percent increase = $(49 - 45.5) \div 45.5 \times 100 \approx 7.7\%$.

11. For any press over the face or chest (such as a dumbbell floor or bench press). The spotter stands or kneels ready to help lift or guide the weight so the lifter can never be trapped under it.
12. Answers vary. Full credit for: a maximum lift puts very high loads on joints, growing bones and form, raising injury risk, especially for less experienced lifters; a moderate set with good form is much safer; formulas such as $\text{load} \times (1 + \text{reps} \div 30)$ give a useful estimate; tracking the estimate over weeks still shows progress.

UNIT CHALLENGE: FOUR WEEKS OF POWER AND STRENGTH

Follow your plans for four weeks: two plyometric sessions a week (from Lesson 4.1's progression) and two or three strength sessions a week (from Lesson 4.2), with rest days between. Present your needs analysis, both plans, a log of every session with contacts or loads and reps, your jump tests and estimated maximums at the start and end of the four weeks with percent changes, and a parent's note on your landings and lifting form. Finish with a page on what you learned.

LOOK FOR	WHAT IT MEANS
Thoughtful analysis	A needs analysis that clearly connects your sport's movements, energy systems and injuries to your chosen exercises.
Safe, faithful training	About 16–20 sessions logged over four weeks, with counted contacts, supervised free-weight work and rest days.
Good form	A parent's note confirming soft landings, a flat back on hinges, a spotter for presses and no maximum lifts.
Accurate retest	Jump tests and estimated maximums before and after, with calculations and percent changes shown.
Reflection	A page using the words power, stretch-shortening cycle, specificity and progressive overload, judged on effort and improvement, not the size of the numbers.

4.1 POWER AND PLYOMETRICS

OBJECTIVES

- Tell how Yuri Verkhoshansky’s shock method and Ray Ewry’s jumping led to modern plyometric training.
- Explain power and the stretch-shortening cycle: the stretch, the turn-around and the shortening.
- Learn safe landings and complete a low-volume plyometric session with counted foot contacts.
- Measure vertical and broad jumps, calculate jump height from hang time, and retest.

Warm-up. Jog easily for 3 minutes. Then do 10 squats, 10 walking lunges, 10 leg swings each way on each leg, 10 calf raises, 20 seconds of skipping, 20 seconds of quick in-place hops on both feet, and 3 short accelerations of about 15 yards. Think about it: why can you jump higher if you dip quickly before you jump than if you squat down, pause for three seconds, and then jump?

WATCH

Plyometrics Training | Duke Health

Duke Health • 2:43

<https://www.youtube.com/watch?v=WqTayB5NTaw>

WHEN TO WATCH

After the “How your body works” paragraph. Watch the good and bad landings closely, then practice the landing yourself before the session.

Note: Duke Sports Medicine physical therapists explain plyometrics and show good and poor landing positions, with a student athlete demonstrating jumps.

BACKUP VIDEO

How to Progress Plyometrics | 5 Levels From Beginner to Advanced

The Movement System • 5:52

https://www.youtube.com/watch?v=_YudFDcW_lw

To see the first levels (snap-downs, drop-and-freeze, box jumps, vertical jumps) before your session.

KEY TERMS

power

The rate of doing work: $\text{force} \times \text{velocity}$, or $\text{work} \div \text{time}$. A powerful athlete produces a large force quickly.

stretch-shortening cycle

A quick stretch of a muscle-tendon unit (eccentric phase), a brief turn-around (amortization phase), and an immediate powerful shortening (concentric phase), which produces more force than shortening alone.

amortization phase

The brief moment between landing and takeoff. The shorter it is, the more stored elastic energy and reflex help are used.

plyometrics

Jumping, hopping and bounding exercises that train the stretch-shortening cycle; named by the coach Fred Wilt in 1975.

foot contact

Each time a foot (or both feet together) lands in a plyometric drill; coaches count contacts to control the training amount.

CORE IDEAS

The story. Ray Ewry was born in Lafayette, Indiana, in 1873. As a boy he caught polio, and doctors feared he would never walk well. He did exercises to strengthen his legs, especially jumping exercises, and by the time he studied engineering at Purdue University he was a champion jumper. He specialized in the standing jumps (high jump, long jump and triple jump from a standstill, with no run-up), and he won all three at the 1900 Olympics in Paris and again in 1904 in St. Louis, and the two still held in 1908 in London: eight Olympic gold medals. Half a century later, in the Soviet Union, the sports scientist and jumps coach Yuri Verkhoshansky studied how jumpers produce force so quickly. In the 1960s he developed the “shock method”: the athlete drops from a box, lands, and immediately rebounds upward, so the leg muscles are stretched hard and then contract at once.

How they figured it out. Verkhoshansky measured the forces and times of takeoffs and found that his “depth jumps” trained the very thing jumpers needed: a strong,

fast rebound after a hard landing. He published his results in the mid-1960s, and Soviet and East European jumpers and sprinters who trained this way won many medals. He also insisted that the shock method was for well-prepared athletes with years of strength training, used in small amounts. Western coaches noticed. In 1975 the American track coach Fred Wilt, watching Soviet athletes warm up with quick jumps, coined the word **plyometrics** (from Greek words meaning “increase” and “measure”). Today sports-medicine groups recommend simple plyometrics for young athletes, beginning with landing practice and low-level jumps, because they improve power and, as the 11+ studies showed, help prevent injuries.

How your body works. **Power** = force $\times$ velocity. When you land and rebound, three things happen in the **stretch-shortening cycle**. First, in the **eccentric** phase, the muscles and tendons of the hips, knees and ankles are stretched as they brake the landing; the tendons store elastic energy like a spring, and stretch sensors in the muscles (muscle spindles) trigger a reflex contraction. Second, the **amortization** phase is the turn-around; if it is short, the stored energy and reflex are used, and if it is long, much of it is lost as heat. Third, in the **concentric** phase, the muscles shorten powerfully for takeoff. That is why a quick dip gives a higher jump than a slow squat with a pause. Physics lets you measure the result: a jumper rises and falls for equal times, so jump height $h = g \times t^2 \div 8$, where t is the hang time in the air and $g = 9.81 \text{ m/s}^2$. Worked example: a hang time of 0.50 seconds gives $h = 9.81 \times 0.25 \div 8 \approx 0.31 \text{ m}$, about 12 inches.

Good form. Landing comes before jumping. Land softly on the balls of the feet, hips back, knees bent and over the toes, chest up, arms ready; “stick” each landing for a full second before you add a second jump. Count **foot contacts**: a beginner’s session should be small, about 50–80 contacts, on grass or a firm, non-slip floor, with full rest between sets and at least 48 hours between plyometric sessions. No depth jumps from boxes in this course.

Try it. This week you will measure your vertical jump and standing broad jump, learn landings, do a low-volume plyometric session, and retest at the end of the week.

PICTURE STUDY



Ray Ewry in the Standing High Jump, London Olympic Games, Unknown photographer, 1908 · Photograph · Olympic Stadium, Shepherd's Bush, London
Image: [Wikimedia Commons](#), public domain

Ray Ewry won the standing high jump at the 1908 London Olympics, when he was 34 years old. In the standing jumps the athlete takes off from both feet with no run-up, so every inch of height comes from the power of the legs and the swing of the arms. The standing jumps were dropped from the Olympics after 1912, and Ewry's eight individual gold medals stood as the Olympic record until 2008.

Look closely

- Look at Ewry's legs. How has he tucked and swept them to clear the bar?
- Look at the uprights and bar. About how high do you think the bar is compared with the people sitting nearby?
- Find the officials and athletes in the background. What are they doing?
- Look at the sand below the bar. Why would a soft landing area matter?

Talk about it

1. A standing jump has no run-up. Where does all the power come from?
2. Ewry built his legs with jumping exercises after polio. How is that like progressive training in this lesson?

3. Why do you think coaches in this course insist on landing practice before high jumps?

Safety first. Jump only with a knowledgeable adult present, after a full warm-up, on grass or a firm, non-slip floor in good shoes, with plenty of space. Keep the session small (about 50–80 foot contacts), rest fully between sets, stop the moment landings become loud or knees cave in, and allow at least 48 hours before the next jump session. No depth jumps or box drops, and stop at any sharp or joint pain.

ACTIVITY

Land, Jump, Measure

You will measure your power, learn to land, do a carefully counted plyometric session, and retest. The numbers belong to you; the goal is better landings and a small, honest improvement.

You will need

- A wall with space beside it, chalk (or a small piece of tape) and a tape measure
- A line on grass or a non-slip floor for the broad jump
- A helper with a phone camera that shows frames or slow motion (optional, for hang time)
- Your fitness journal with a contact count table

Steps

1. **Vertical jump test (Session 2).** Chalk your fingertips. Stand sideways to the wall, feet flat, and reach up as high as you can; mark it. Then, from a standstill, dip quickly and jump, touching the wall as high as you can. Measure from the reach mark to the jump mark. Take 3 tries with 1 minute of rest; record the best. If your helper films a jump, count the frames from takeoff to landing and divide by the frame rate to get hang time; calculate $h = 9.81 \times t^2 \div 8$ and compare with your wall measurement.
2. **Standing broad jump test.** Toes behind the line, swing your arms and jump forward as far as you can, landing on both feet and sticking the landing. Measure to the back of your nearest heel. Best of 3.
3. **Landing drills (12 contacts).** Snap-downs: rise onto your toes with arms overhead, then snap quickly down into a landing position (hips back, knees bent over toes) and hold 2 seconds; 2 sets of 6.
4. **Squat jump and stick (10 contacts).** Dip, jump straight up, land softly and hold the landing for 2 seconds. 2 sets of 5, with 60 seconds of rest.
5. **Broad jump and stick (8 contacts).** Jump forward about three-quarters of your best distance and stick the landing. 2 sets of 4, walking back between jumps.

6. **Line hops (40 contacts).** Hop forward and back over a line on both feet, quick and light, for 10 contacts; rest 30 seconds; then side to side for 10. Do 2 rounds. Total for the session: about 70 contacts.
7. **Cool down and record.** Walk 3 minutes and stretch calves, thighs, hamstrings and hips. Record each drill, the contacts, and a landing-quality score (1–5).
8. **Session 3 (at least 48 hours later).** Repeat the warm-up and the session with the same contact count, aiming for quieter landings and quicker line hops. Then retest the vertical and broad jumps and compare. Write which improved and whether it came from your muscles or your technique.

Tips

- Arm swing adds several inches to a jump. Swing back as you dip and up hard as you jump.
- Quality ends the set. If a landing is loud or a knee caves, stop that drill for the day.
- Plyometrics work best when you are fresh, after the warm-up and before tiring exercise.

Check your work

- ☐ I can explain power and the stretch-shortening cycle, and how plyometrics began.
- ☐ I can land softly and completed a counted session of about 70 contacts.
- ☐ I measured, calculated and retested my jumps.

FITNESS JOURNAL

1. Record both test days (vertical and broad jumps, best of 3) and both sessions (drills, contacts, landing scores).
2. Show the hang-time calculation for your own jump, or for a hang time of 0.45 s, step by step, in meters and inches.
3. Draw the three phases of the stretch-shortening cycle in a countermovement jump as stick figures, labeling eccentric, amortization and concentric.
4. Write a four-week plyometric progression: two sessions a week, contacts rising from about 60 to 100, with harder drills added only when landings are excellent.

From history. Yuri Verkhoshansky (1928–2010) worked for many years at sports-science institutes in Moscow and wrote books on special strength training that were translated into English in the 1970s and 1980s. The American sports scientist and translator Michael Yessis helped bring his work to American coaches, and Fred Wilt worked with Yessis to share Soviet training methods for running and jumping.

COMMON MISTAKES

- Jumping before learning to land. Landing mechanics come first.
- Doing hundreds of jumps. A small number of quality contacts trains power; too many invites overuse injuries.
- Pausing on the ground between rebounds in line hops. Quick, light contacts train the stretch-shortening cycle.
- Trying depth jumps from high boxes without years of strength training and a coach.

Make it a game • Jump Height Duel. Stand beside a wall and mark your standing reach, then jump and mark the highest touch. Measure the difference. Try a countermovement versus a squat jump and compare. Name the stretch, turn-around and shortening phases of the stretch-shortening cycle. Land softly every time. A parent supervises. Beat your personal best next session.

4.2 STRENGTH FOR YOUR SPORT

OBJECTIVES

- Tell how Boyd Epley and the strength-coaching profession began, and what a needs analysis is.
- Analyze your sport's movements, energy systems and common injuries, and choose exercises from the five movement patterns.
- Learn the goblet squat, dumbbell Romanian deadlift, push or press, one-arm row and farmer's carry with good form, under a knowledgeable adult's supervision.
- Estimate strength from a set of 8–10 reps instead of a maximum lift, and write a sport-specific plan.

Warm-up. Jog or skip for 3 minutes. Then do 10 bodyweight squats, 10 hip hinges with a broom handle held along your back (head, upper back and tailbone touching it), 10 push-ups at your level, 10 band or towel pull-aparts, 10 reverse lunges on each leg and a 30-second plank. Think about it: does a swimmer need the same strength as a soccer goalkeeper? What would you ask before you wrote a plan for either one?

WATCH

Programming for Resistance Training | Needs Analysis | CSCS Chapter 17

Dr. Jacob Goodin · 15:13

<https://www.youtube.com/watch?v=E6ZbXI7rexk>

WHEN TO WATCH

After the “How they figured it out” paragraph. Copy the two parts of a needs analysis and the three questions about the sport into your journal; pause on the table of sample athletes.

Note: A university exercise-science professor teaches the needs-analysis step of program design from the NSCA's textbook, with slides. It is made for students preparing for a strength-coaching certification, so it is detailed; the channel also advertises a study course for that exam.

KEY TERMS

needs analysis

The first step of program design: evaluating the sport (movements, energy systems, common injuries) and the athlete (training experience, test results, goals).

movement patterns

The basic ways the body produces force: squat, hinge, push, pull and carry (with lunges and rotation as further patterns).

estimated maximum

A prediction of the most a person could lift once, calculated from a set of several reps; it lets coaches plan loads without dangerous maximum-lift testing.

specificity

The principle that the body adapts to the particular demands placed on it, so training should match the sport's movements and energy needs.

spotter

A trained helper who stands ready to assist with a lift, especially a press over the face or chest, so the lifter can never be trapped under a weight.

CORE IDEAS

The story. In the 1960s many coaches still believed lifting weights would make athletes slow and stiff. Boyd Epley, a pole vaulter at the University of Nebraska who had hurt his back, began helping injured teammates in the weight room. In 1969, at the urging of assistant coach Tom Osborne, head football coach Bob Devaney hired him, making him one of the first full-time strength coaches in American college sports. Epley built a weight room, tested athletes regularly, and showed that strong, powerful players were faster and stayed healthier. In 1978 he gathered strength coaches in Lincoln, Nebraska, and founded what became the National Strength and Conditioning Association (NSCA).

How they figured it out. Strength coaches learned that a good program does not start with a list of exercises but with questions. A **needs analysis** asks about the sport: What movements does it use (jumping, sprinting, throwing, pulling, cutting)? Which energy systems (short bursts or long efforts)? Where do injuries most often happen?

Then it asks about the athlete: How experienced is he or she in training? What do tests show? What season is it? Coaches also needed a safe way to set loads without asking athletes to lift as much as they possibly could once, which strains joints and form. They used formulas that estimate a maximum from a set of reps. One widely used formula, often credited to Epley, is: $\text{estimated max} = \text{load} \times (1 + \text{reps} \div 30)$.

How your body works. Muscles adapt specifically to what they are asked to do: heavy, slow work builds strength; fast work builds power; long sets build muscular endurance. But almost every sport rests on the same few **movement patterns**: the **squat** (knees and hips bend together: jumping, landing), the **hinge** (hips push back with a flat back: sprinting, tackling, lifting from the floor), the **push** (pressing away: blocking, throwing), the **pull** (rowing, climbing, swimming strokes) and the **carry** (holding the trunk steady under load: almost everything). A soccer player might emphasize single-leg squats, hinges and the hamstrings; a swimmer pulls and builds shoulder strength in balance; a volleyball player needs squats, landings and shoulder care. For high-school athletes, 2–3 strength sessions a week in the off-season and 1–2 shorter ones in season, with 2–3 sets of 6–12 reps of each main exercise, stopping each set with 2–3 good reps left in reserve, build strength safely.

Good form. Free weights are used only with a **knowledgeable adult present**. Learn every lift with a broom handle or very light load first. Keep a neutral back, brace your trunk with a breath before each rep, and breathe out as you finish it. Any press over the face or chest has a **spotter** standing ready. Never test a one-repetition maximum. Worked example: a student does 10 good goblet squats holding a 30-pound dumbbell. $\text{Estimated max} = 30 \times (1 + 10 \div 30) = 30 \times 1.33 = 40$ pounds. A 25-pound dumbbell row for 8 reps: $25 \times (1 + 8 \div 30) \approx 25 \times 1.27 \approx 31.7$ pounds. These estimates are tracked over weeks to see strength grow, without ever lifting the maximum itself.

Try it. This week you will write a needs analysis for your sport, learn five main lifts with light loads, do a test set of 8–10 reps for each to estimate your strength, and write a sport-specific plan. Scripture says, “Whatsoever thy hand findeth to do, do it with thy might” (Ecclesiastes 9:10): train with your might, and with wisdom.

PICTURE STUDY



Calling in the Gleaners, Jules Breton, 1859 · Oil on canvas · Musée d'Orsay, Paris

Image: [Wikimedia Commons](#), public domain

Jules Breton grew up in the farming village of Courrières in northern France. By old custom, poor families could glean, picking up the grain left after the harvest, but only at set hours. Here, as the sun sets, the field guard blows his horn to call the gleaners in, and the women gather up the day's work to carry home. Their strength was built, day after day, by exactly the movements the work demanded.

Look closely

- Find the women bending to gather grain. Which movement pattern are they using: squat, hinge, push, pull or carry?
- Find the young woman balancing a sheaf on her head and the woman carrying bundles in both arms. How are they standing to carry the load safely?
- Find the field guard with the horn. What is he announcing?
- Look at the sky and the moon. What time of day is it, and how long might these women have worked?

Talk about it

1. Do a quick needs analysis for gleaning: which movements, which energy systems and which body parts would most need to be strong?

2. Which exercises from this lesson would best prepare someone for this work?
3. How is training for your sport like the gleaners' daily work, and how is it different?

Safety first. Use free weights only with a knowledgeable adult present, after a full warm-up, in a clear space with a flat, non-slip floor and good shoes. Learn each lift with a broom handle first, add load only when form is perfect, have a spotter for any press over the face or chest, and never attempt a one-repetition maximum. Stop at sharp pain or joint pain, and keep at least one day of rest between strength sessions for the same muscles.

ACTIVITY

Needs Analysis and Strength Plan

You will think like a strength coach: analyze your sport, learn the lifts, estimate your strength safely and write a plan that fits your season. If you do not play a team sport, choose an activity you love (hiking, running, swimming, cycling, farm work) and analyze that.

You will need

- A broom handle, and light dumbbells or a kettlebell (or water jugs and a backpack with books)
- A sturdy bench or a step and a mat
- A knowledgeable adult to supervise and spot
- Your fitness journal

Steps

1. **Write the needs analysis (Session 1 or 2).** For your sport: list five key movements, the main energy systems (short bursts, repeated sprints, long steady efforts), the three most common injuries, and the season dates. For yourself: training experience, results from your Lesson 4.1 jump tests and Lesson 1.2 balance test, and two goals.
2. **Learn the lifts with a broom handle (Session 2).** Goblet squat (hold the weight at your chest, sit between your heels, chest up). Romanian deadlift (soft knees, push hips back with a flat back until you feel the hamstrings, then stand). Push: push-up at your level, or a dumbbell floor press with a spotter kneeling beside you. One-arm dumbbell row (one hand and knee on a bench, flat back, pull the weight to your hip). Farmer's carry (a weight in each hand, stand tall, walk 20 yards). A parent watches every movement.
3. **Add light loads.** For each lift, choose a load you can lift 12 times with perfect form, and do 1 set of 8. Rest 2 minutes between exercises.
4. **Test set.** For each of the first four lifts, do 1 set of 8–10 good reps with a moderate load, stopping before form breaks. Record the load and reps, and calculate the estimated maximum with $\text{load} \times (1 + \text{reps} \div 30)$. For the carry,

record the distance or time you can walk with good posture, up to 60 seconds.

5. **Write the plan.** Choose 5–6 exercises covering squat, hinge, push, pull and carry, plus one exercise for your sport’s common injury (for example, single-leg balance for ankles, hamstring lowers for knees, band rotations for shoulders). Write sets (2–3), reps (6–12), rest (60–120 seconds), days per week for your season, and a double-progression rule: add reps until the top of the range, then add a little load.
6. **Session 3: do the first workout.** Warm up, then do the plan exactly, logging every set with load, reps and reps left in reserve. Your adult checks form on each lift.
7. **Cool down and reflect.** Walk 3 minutes and stretch. Write which lift felt strongest, which needs the most practice, and how each one connects to your sport.

Tips

- Lift the weight under control: about 2 seconds down, a steady but strong drive up.
- Write next workout’s targets in your journal before you start.
- In season, a short, twice-a-week strength session keeps the strength you built without leaving you tired for games.

Check your work

- ☐ I can explain a needs analysis and the five movement patterns.
- ☐ I learned five lifts with good form, supervised, and estimated my strength from test sets.
- ☐ I wrote a sport-specific plan with sets, reps, rest, days and a progression rule.

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1. Copy your needs analysis: sport movements, energy systems, common injuries, season and your own goals.
2. Record your test sets with each estimated-maximum calculation shown step by step.

3. Copy your strength plan as a table, and draw a stick figure of each lift with two form cues.
4. Write a paragraph explaining why this course estimates strength from a set of reps instead of testing a maximum.

From history. Boyd Epley served for 35 years as Nebraska's head strength coach. The NSCA, which he founded in 1978, later created the Certified Strength and Conditioning Specialist credential and published position statements on youth training stating that supervised, well-designed strength training is safe and beneficial for young people.

COMMON MISTAKES

- Copying a professional athlete's program. Your plan should fit your sport, your season and your experience.
- Adding weight before form is solid, or lifting without a knowledgeable adult present.
- Rounding the back on the Romanian deadlift. Push the hips back and keep the back flat.
- Testing a one-rep max. Estimate it from a set of 8–10 instead, and track the estimate over time.

Make it a game • Sport Needs Analysis. Pick a sport and give your parent a sixty-second needs analysis: movements, energy systems, common injuries. Then choose five exercises, one from each movement pattern. She challenges your choices with specificity questions. Tell Boyd Epley's story. Switch roles with her sport. Most defensible plan wins.

Scripture. “Whatsoever thy hand findeth to do, do it with thy might” (Ecclesiastes 9:10, KJV)

Training for your sport is one of the tasks your hands find to do. Do it with your might, and with the wisdom of a good plan and good form.

UNIT 4

STRENGTH

Strength is the ability to produce force. Power is the ability to produce it fast, and nearly every sport depends on it: the jump for a rebound, the first steps of a sprint, the swing of a bat. In the 1960s the Soviet sports scientist Yuri Verkhoshansky developed what he called the “shock method,” jumps in which the muscles are stretched hard and then contract at once, and in 1975 the American coach Fred Wilt gave such training the name “plyometrics.” Long before, Ray Ewry, a boy who had polio, built his legs with jumping exercises and won eight Olympic gold medals in the standing jumps. In this unit you will learn how the stretch-shortening cycle works, why landing well comes first, and how to train power with low volume and good form, measuring your jump height with a little physics.

Then you will design strength training for your own sport. In 1969 the University of Nebraska hired Boyd Epley, a former pole vaulter, as one of the first full-time strength coaches in college sports, and in 1978 he founded the National Strength and Conditioning Association. Coaches like him taught that a good program begins with a needs analysis: what does this sport demand, and what does this athlete need? You will analyze your sport, choose exercises from the five main movement patterns (squat, hinge, push, pull and carry), learn them with light free weights or household loads under a knowledgeable adult’s eye, and estimate your strength safely from a set of 8–10 reps, never from a maximum lift.

PREREQUISITES

- Knows good form for the squat, hinge, push-up, row and lunge with body weight (earlier grades)
- Knows sets, reps, rest and progressive overload, and the slow- and fast-twitch fibers
- Can land softly from a jump with knees over toes (Lesson 1.2)

MASTERY CHECKLIST

- ☐ I can explain power, the stretch-shortening cycle and how Verkhoshansky's shock method led to plyometrics.
- ☐ I can land safely and do a low-volume plyometric session, counting foot contacts.
- ☐ I can calculate jump height from hang time and measure a vertical jump.
- ☐ I can do a needs analysis for a sport and choose exercises from the five movement patterns.
- ☐ I can train with light free weights safely, with a spotter for pressing, and estimate strength from a set of 8–10 reps instead of a maximum lift.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“Strength Training” (Nemours KidsHealth for Teens)**: Free. A teen article on how strength training works, supervision, form and safety. Read it with Lesson 4.2.
- **Light dumbbells or a kettlebell**: Optional, for Lesson 4.2, used only with a knowledgeable adult present. Water jugs, a backpack with books and push-ups do the same jobs.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

4.1 Power and Plyometrics

3 sessions of 45–50 minutes

4.2 Strength for Your Sport

3 sessions of 45–50 minutes

UNIT 4 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. 8 pts

Who was Ray Ewry, and how does his story connect to jump training?

2. 8 pts

What was Yuri Verkhoshansky's shock method, and who coined the word "plyometrics"?

3. 10 pts

Name and describe the three phases of the stretch-shortening cycle, and explain why a short middle phase gives a higher jump.

4. 10 pts

A jumper's hang time is 0.60 seconds. Using $h = g t^2 \div 8$ with $g = 9.81 \text{ m/s}^2$, find the jump height in meters and in inches ($1 \text{ m} \approx 39.4 \text{ in}$).

5. 8 pts

List four safety rules for plyometric training in this course.

6. 8 pts

A session has snap-downs 2×6 , squat jumps 2×5 , broad jumps 2×4 and line hops 4×10 . How many foot contacts is that? Is it suitable for a beginner?

7. 8 pts

Who was Boyd Epley, and why does his work matter for high-school athletes?

8. 8 pts

What are the two parts of a needs analysis? Give three questions about the sport.

9. 8 pts

Name the five movement patterns, and give one sport action and one exercise for each.

10. **10 pts**

A student does 9 good reps of a dumbbell Romanian deadlift with a 35-pound dumbbell. Use estimated max = load $\times$ (1 + reps $\div$ 30). Four weeks later she does 12 reps with the same dumbbell. Find both estimates and the percent increase.

11. **6 pts**

When is a spotter required in this course, and what does the spotter do?

12. **8 pts**

In three to five sentences, explain why this course estimates strength from a set of 8–10 reps instead of testing a one-repetition maximum.

ANSWER KEY

1. An American jumper (born 1873) who had polio as a boy and built up his legs with jumping exercises; at Purdue he became a champion and won eight Olympic gold medals in the standing jumps (1900, 1904, 1908). Repeated jumping training built his leg power.
2. A Soviet training method of the 1960s using depth jumps: dropping from a box, landing and immediately rebounding, so the muscles are stretched hard and then contract at once; intended for well-prepared athletes in small amounts. The American coach Fred Wilt coined “plyometrics” in 1975.
3. Eccentric: muscles and tendons stretch while braking, storing elastic energy and triggering the stretch reflex. Amortization: the brief turn-around. Concentric: the muscles shorten powerfully for takeoff. A short amortization phase uses the stored elastic energy and reflex before they are lost as heat.
4. $h = 9.81 \times 0.36 \div 8 = 3.5316 \div 8 \approx 0.44$ m. In inches: $0.44 \times 39.4 \approx 17.4$ in.
5. Any four: knowledgeable adult present; full warm-up; grass or firm non-slip floor and good shoes; learn landings first; low volume (about 50–80 contacts for beginners); full rest between sets; at least 48 hours between sessions; stop when landings get loud or knees cave; no depth jumps or box drops; stop at sharp or joint pain.
6. $12 + 10 + 8 + 40 = 70$ contacts. Yes; it is within the beginner range of about 50–80.
7. A former Nebraska pole vaulter hired in 1969 as one of the first full-time college strength coaches; he founded the NSCA in 1978. He helped establish strength and conditioning as a profession and showed that well-planned strength training makes athletes faster, more powerful and less injured; the NSCA now sets standards and supports safe youth training.
8. Evaluation of the sport and assessment of the athlete. Sport questions: What movements does it use? Which energy systems? Where do injuries most often occur? (Also: what is the season?)
9. Examples: squat (landing a jump; goblet squat); hinge (sprint start or tackle; Romanian deadlift); push (blocking or throwing; push-up or press); pull (swimming stroke or climbing; row); carry (holding steady against contact; farmer’s carry).
10. Before: $35 \times (1 + 9/30) = 35 \times 1.30 = 45.5$ lb. After: $35 \times (1 + 12/30) = 35 \times 1.40 = 49$ lb. Percent increase = $(49 - 45.5) \div 45.5 \times 100 \approx 7.7\%$.

11. For any press over the face or chest (such as a dumbbell floor or bench press). The spotter stands or kneels ready to help lift or guide the weight so the lifter can never be trapped under it.
12. Answers vary. Full credit for: a maximum lift puts very high loads on joints, growing bones and form, raising injury risk, especially for less experienced lifters; a moderate set with good form is much safer; formulas such as $\text{load} \times (1 + \text{reps} \div 30)$ give a useful estimate; tracking the estimate over weeks still shows progress.

UNIT CHALLENGE: FOUR WEEKS OF POWER AND STRENGTH

Follow your plans for four weeks: two plyometric sessions a week (from Lesson 4.1's progression) and two or three strength sessions a week (from Lesson 4.2), with rest days between. Present your needs analysis, both plans, a log of every session with contacts or loads and reps, your jump tests and estimated maximums at the start and end of the four weeks with percent changes, and a parent's note on your landings and lifting form. Finish with a page on what you learned.

LOOK FOR	WHAT IT MEANS
Thoughtful analysis	A needs analysis that clearly connects your sport's movements, energy systems and injuries to your chosen exercises.
Safe, faithful training	About 16–20 sessions logged over four weeks, with counted contacts, supervised free-weight work and rest days.
Good form	A parent's note confirming soft landings, a flat back on hinges, a spotter for presses and no maximum lifts.
Accurate retest	Jump tests and estimated maximums before and after, with calculations and percent changes shown.
Reflection	A page using the words power, stretch-shortening cycle, specificity and progressive overload, judged on effort and improvement, not the size of the numbers.

UNIT 5

AEROBIC TRAINING

Two numbers explain much of endurance: how much oxygen your body can use at most (VO_2 max) and how close to that ceiling you can work before fatigue builds quickly (the lactate threshold). In 1923 the British physiologist A. V. Hill described the first; in 1964 the American physician Karlman Wasserman, measuring the breathing of heart patients on exercise machines, described a “threshold” that became the second. In this unit you will learn how oxygen delivery and use set VO_2 max, what really happens to lactate in hard exercise, and why threshold training is the heart of endurance. You will estimate your VO_2 max with Kenneth Cooper’s 12-minute run and do a threshold workout.

Then you will plan and run a race. On October 14, 1964, at the Tokyo Olympics, a little-known U.S. Marine lieutenant named Billy Mills, who had never run 10,000 meters faster than 29 minutes, stayed with the leaders and then sprinted past them on the final straight to win in an Olympic-record 28:24.4. You will learn the science of pacing, predict your own 5K time from your test, write a race plan with splits, run it, and lead your family in a fitness day to close the quarter.

PREREQUISITES

- Knows aerobic and anaerobic energy, heart rate, stroke volume and cardiac output (earlier grades)
- Can find a pulse, use an effort rating and do interval training
- Can work with formulas, decimals, exponents on a calculator and minutes-and-seconds arithmetic

MASTERY CHECKLIST

- ☐ I can explain VO_2 max and what limits it, using the Fick equation in words.
- ☐ I can explain lactate threshold, what lactate really is and why threshold training improves endurance.
- ☐ I can estimate VO_2 max from a 12-minute run and estimate heart-rate training zones.
- ☐ I can predict a race time, plan even or negative splits and pace a race.
- ☐ I can plan and lead a family fitness day.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A heart-rate monitor or sports watch:** Optional, for the threshold workout and race. Counting your pulse for 15 seconds right after each repeat works well too.
- **A stopwatch with a lap button:** Optional; a phone timer does the same job for the 12-minute run, the threshold repeats and race splits.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

5.1 Lactate Threshold and VO₂ Max

3 sessions of 45–50 minutes

5.2 A Race Plan: 5K or 10K

3 sessions of 45–50 minutes

UNIT 5 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

What did A. V. Hill and Hartley Lupton discover in the 1920s, and what did Karlman Wasserman describe in 1964?

2. **8 pts**

Write the Fick equation in words and name three training adaptations that raise VO₂ max.

3. **8 pts**

Explain what happens to blood lactate as running speed increases, and define the lactate threshold.

4. **6 pts**

Is lactate a waste product that causes next-day soreness? Explain.

5. **10 pts**

A student runs 2,750 meters in Cooper's 12-minute test. Estimate her VO₂ max with $\text{VO}_2 \text{ max} \approx (d - 504.9) \div 44.73$, and find her average pace per kilometer.

6. **8 pts**

Estimate the maximum heart rate of a 17-year-old with $HR_{max} \approx 208 - 0.7 \times \text{age}$, and a threshold range of 85–90 percent of it.

7. **8 pts**

Describe Billy Mills's 1964 Olympic 10,000-meter race and the plan that helped him win.

8. **8 pts**

Why do world records from 5,000 meters to the marathon tend to be run at even pace? Use the lactate threshold in your answer.

9. **10 pts**

Using Riegel's formula $T_2 = T_1 \times (D_2 \div D_1)^{1.06}$, predict a 10K time for a runner who ran 5K in 24:00. (Use $2^{1.06} \approx 2.085$.)

10. **10 pts**

A runner planned 5K splits of 5:20, 5:15, 5:15, 5:15, 5:10. Her actual splits were 5:00, 5:12, 5:25, 5:35, 5:30. Find the planned and actual totals and the difference. What kind of split did she run, and what was her likely mistake?

11. **6 pts**

List four parts of a complete race plan.

12. **10 pts**

In four to six sentences, explain how Hebrews 12:1 and the science of pacing fit together, and describe the family fitness day you led.

ANSWER KEY

1. Hill and Lupton found that oxygen use rises with running speed until it levels off at a maximum, the maximum oxygen intake ($\text{VO}_2 \text{ max}$). Wasserman, testing heart patients, found the point where breathing rises faster than oxygen use and blood lactate begins to climb, which he called the anaerobic threshold (now lactate threshold).
2. $\text{VO}_2 = \text{cardiac output (stroke volume} \times \text{heart rate)} \times \text{oxygen extraction (arterial minus venous oxygen content)}$. Adaptations: larger stroke volume, more blood volume, more capillaries, more mitochondria (any three).
3. At easy speeds lactate stays near resting levels (about 1 mmol/L) because it is cleared as fast as it is produced; as speed rises, production eventually exceeds clearance and lactate climbs steeply. The lactate threshold is the intensity above which lactate builds up faster than it can be cleared, so fatigue comes much sooner.
4. No. Lactate is a fuel, carried to the heart, other muscles and the liver and used for energy (George Brooks's lactate shuttle); it is cleared within about an hour after exercise. Next-day soreness comes from small strains in muscle fibers.
5. $(2,750 - 504.9) \div 44.73 = 2,245.1 \div 44.73 \approx 50.2 \text{ mL/kg/min}$. Pace: $12 \text{ min} \div 2.75 \text{ km} \approx 4.36 \text{ min/km} \approx 4:22 \text{ per km}$.
6. $208 - 0.7 \times 17 = 208 - 11.9 = 196.1 \approx 196 \text{ bpm}$. 85% $\approx 167 \text{ bpm}$; 90% $\approx 176 \text{ bpm}$. Threshold range about 167–176 bpm.
7. Mills, a little-known Marine officer who had never broken 29 minutes, stayed relaxed with the leaders while Ron Clarke pushed the pace; on the last lap he was jostled and fell back as Gammoudi surged, then swung wide on the final straight and sprinted past both to win in an Olympic record 28:24.4. His plan: stay with the leaders, avoid wasting energy, save a final sprint.
8. Running much faster than sustainable early pushes the runner well above lactate threshold, so lactate and acidity build and glycogen is used fast, forcing a large slowdown later; even pacing keeps effort near threshold and spends energy most efficiently, with a slight surge only at the end.
9. $T_2 = 24 \times 2^{1.06} \approx 24 \times 2.085 \approx 50.04 \text{ min} \approx 50:02$. Pace about 5:00 per km.
10. Planned: $5:20 + 5:15 \times 3 + 5:10 = 5:20 + 15:45 + 5:10 = 26:15$. Actual: $5:00 + 5:12 + 5:25 + 5:35 + 5:30 = 26:42$. She was 27 seconds slower than planned. A positive split: she started 20 seconds too fast, went above threshold and slowed badly.

11. Any four: goal time; splits per kilometer or mile; warm-up; pre-race meal and timing; fluids; where to push; what to do if starting too fast or if a problem comes; cool-down.
12. Answers vary. Full credit for: Hebrews 12:1 calls us to run with patience, and pacing science shows that holding back early and running evenly gives the best race; patience and faithfulness over the whole distance matter in training and in life; a clear description of the fitness day (warm-up, race, water table, meal, talk) and what the student learned.

UNIT CHALLENGE: MY RACE AND OUR FAMILY FITNESS DAY

Present your aerobic training and race. Include your 12-minute test and VO₂ max estimate, your threshold workout, a two-week training plan leading to your race (one threshold session, one interval session and easy runs each week), your race plan with predicted splits, your rehearsal, your planned and actual race splits with a graph, your race report, and the family fitness day schedule with a note from a parent. Finish with a one-page reflection on the whole quarter: what you learned about caring for the body God gave you, and the habits you will keep.

LOOK FOR	WHAT IT MEANS
Sound training	A two-week plan with mostly easy running, one threshold and one interval session a week, and the sessions logged with heart rate and effort.
Accurate prediction and plan	Riegel prediction, goal pace and planned splits calculated correctly, with a complete race plan.
Race execution and analysis	Planned and actual splits compared with differences and a graph, and an honest race report.
Family fitness day	A clear schedule, a warm-up the student led, a water table and recovery meal, and a parent's note on how it went.
Quarter reflection	A page connecting sleep, hydration, nutrition, strength and aerobic training, judged on effort, honesty and improvement, not on the size of the numbers.

5.1 LACTATE THRESHOLD AND VO₂ MAX

OBJECTIVES

- Tell how A. V. Hill's oxygen ceiling and Karlman Wasserman's threshold were discovered.
- Explain VO₂ max with the Fick equation (cardiac output × oxygen extraction) and what training changes.
- Explain lactate threshold, why lactate rises and why it is a fuel, not a waste.
- Estimate VO₂ max with a 12-minute run and complete a threshold workout using heart rate and the talk test.

Warm-up. Walk 2 minutes, jog easily 5 minutes, then do 10 leg swings each way on each leg, 10 walking lunges, 20 seconds of skipping and 3 strides of about 80 yards, building to a fast but relaxed pace. Think about it: in a long race, why can you hold one pace for 30 minutes, but a pace only a little faster for just 10?

WATCH

Aerobic Capacity (VO₂max) and Anaerobic Thresholds

Vivo Phys - Evan Matthews · 11:05

<https://www.youtube.com/watch?v=doxFSOSHk-0>

WHEN TO WATCH

After the “How your body works” paragraph. Copy the graph of blood lactate against running speed and mark where the threshold is.

Note: A university exercise physiologist lectures with slides on VO₂ max, the lactate and ventilatory thresholds and what they mean for endurance performance. It is a college-level lecture; pause to take notes.

KEY TERMS

VO₂ max

The greatest rate at which the body can take in and use oxygen during maximal exercise, usually given in milliliters of oxygen per kilogram of body mass per minute (mL/kg/min).

Fick equation

VO₂ = cardiac output × the difference in oxygen content between arterial and venous blood (how much oxygen the heart pumps out × how much the muscles take from it).

lactate

A product of breaking down glucose quickly for energy. It is produced even at rest, and it is carried to the heart, other muscles and the liver and used as fuel.

lactate threshold

The exercise intensity above which lactate builds up in the blood faster than it can be cleared, so fatigue comes much sooner.

running economy

How much oxygen a runner uses at a given speed; a more economical runner uses less oxygen to run the same pace.

CORE IDEAS

The story. In the 1920s the British physiologist A. V. Hill and his colleague Hartley Lupton had runners circle a grass track while they collected their breath in bags. As the pace rose, oxygen use rose too, until it leveled off: the body had a ceiling, which they called the maximum oxygen intake, now called **VO₂ max**. Forty years later, in 1964, the American physician Karlman Wasserman and his colleague Malcolm McIlroy were testing patients with heart disease on exercise machines, measuring the gases they breathed in and out. They wanted a safe way to judge a patient's fitness without pushing a sick heart to its limit.

How they figured it out. Wasserman noticed that, as the work grew harder, a point came where breathing rose faster than oxygen use, and lactate in the blood began to climb. He called it the **anaerobic threshold**, the point where the muscles began relying more heavily on fast, oxygen-independent energy. Sports scientists soon measured the same turning point in athletes by taking drops of blood during treadmill tests, and found that it predicted endurance performance even better than VO₂ max: two runners with the same VO₂ max could race very differently if one could hold a pace much closer to that ceiling. In the 1980s the physiologist George Brooks showed that lactate is not simply waste: it is shuttled from muscle to muscle, the heart and the liver and used as fuel. Today the term **lactate threshold** is preferred.

How your body works. By the **Fick equation**, $VO_2 = \text{cardiac output} \times \text{oxygen extraction}$: the more blood your heart pumps each minute (stroke volume $\times$ heart

rate), and the more oxygen your muscles pull from it, the higher your VO₂ max. Training enlarges the heart's stroke volume, increases blood volume, grows new capillaries and builds more mitochondria in muscle. Many active teenagers have VO₂ max values of roughly 40–55 mL/kg/min; elite distance runners can exceed 70. At easy paces, blood lactate stays near resting levels (about 1 mmol per liter) because it is cleared as fast as it is made. As pace rises, production eventually outruns clearance, and above the **lactate threshold** lactate and acidity build quickly, breathing becomes labored and fatigue comes in minutes. Untrained people reach it at roughly 50–60 percent of VO₂ max; trained endurance athletes at 75–90 percent. Threshold workouts, “comfortably hard” runs of 20–40 minutes in total, push it higher. Kenneth Cooper’s 12-minute run gives a field estimate: $\text{VO}_2 \text{ max} \approx (\text{distance in meters} - 504.9) \div 44.73$. Worked example: 2,400 meters $\rightarrow (2,400 - 504.9) \div 44.73 = 1,895.1 \div 44.73 \approx 42.4 \text{ mL/kg/min}$.

Think it through. To guide training, estimate your maximum heart rate with the formula $\text{HR}_{\text{max}} \approx 208 - 0.7 \times \text{age}$ (Tanaka and colleagues, 2001). For a 16-year-old: $208 - 0.7 \times 16 = 208 - 11.2 \approx 197$ beats per minute. Threshold running is often around 85–90 percent of maximum, about 167–177 bpm for that student, and feels like an effort of 7 out of 10: you can speak in short phrases but not hold a conversation. Formulas are averages; your own heart may run higher or lower, so use the talk test and effort rating alongside them.

Try it. This week you will run Cooper’s 12-minute test to estimate your VO₂ max and then do a threshold workout, recording heart rate, effort and the talk test.

PICTURE STUDY



The Pair-Oared Shell, Thomas Eakins, 1872 · Oil on canvas · Philadelphia Museum of Art

Image: [Wikimedia Commons](#), public domain

Thomas Eakins rowed on the Schuylkill River in Philadelphia and painted the city's oarsmen many times. Here the brothers John and Barney Biglin practice in a pair-oared shell, passing under a railroad bridge in the evening light. Eakins worked out the exact angle of the sun and the boat's position with careful perspective drawings before he painted.

Look closely

- Look at the two rowers' arms and backs. Are they at the beginning, middle or end of the stroke?
- Look at their faces. Are they racing all-out or rowing at a steady, controlled effort?
- Look at the water around the boat. What does it tell you about their speed?
- Find the great stone pier. How does it make the boat look by comparison?

Talk about it

1. A 2,000-meter rowing race lasts about six to eight minutes. Which matters more for it: VO₂ max, lactate threshold or both? Why?
2. Why might rowers train for long periods at a steady, "comfortably hard" pace like this?

3. How do two rowers in one boat have to share and match their effort? How is that like pacing a race?

Safety first. Do the 12-minute run only if you have been running regularly, after a full warm-up, on a measured track or safe loop with a buddy or adult and water nearby; it is hard but should never feel dizzy or painful. Stop at once and tell an adult at chest pain, dizziness, faintness or trouble breathing, and cool down by walking afterward. Avoid hot, humid days for maximal and threshold efforts.

ACTIVITY

The Ceiling and the Threshold

You will estimate your aerobic ceiling with Cooper's 12-minute run, then train just below your threshold with a classic workout. You will see how heart rate, effort and the talk test line up for you.

You will need

- A 400-meter track or a measured loop (a map app can measure it; mark every 100 meters with chalk if you can)
- A stopwatch with a lap button, and a helper to count laps
- A heart-rate monitor (optional) or a watch for a 15-second pulse count
- Your fitness journal

Steps

1. **Warm up (Session 2).** Do the full warm-up, including the strides. Write the temperature and how you slept.
2. **The 12-minute run.** Run as far as you can in 12 minutes, at the most even pace you can hold. Your helper records laps and calls out each 3 minutes. At 12:00, stop where you are and note the extra distance past the last full lap. Take your pulse for 15 seconds right away and multiply by 4.
3. **Calculate.** Total meters = laps $\times$ 400 + extra meters. $VO_2 \text{ max} \approx (\text{meters} - 504.9) \div 44.73$. Average pace per kilometer = 12 minutes $\div$ (meters $\div$ 1,000). Also find your estimated maximum heart rate ($208 - 0.7 \times \text{age}$) and a threshold range (85–90 percent of it).
4. **Cool down.** Walk and jog easily for 5–10 minutes and stretch calves, thighs, hamstrings and hips.
5. **Session 3 (at least 48 hours later): threshold workout.** Warm up for 10 minutes of easy jogging. Then run 3×6 minutes at a “comfortably hard” pace (effort 7/10; you can say short phrases, not sentences), with 2 minutes of easy jogging between. Aim for even pace in all three repeats.
6. **Record each repeat:** distance (or laps), heart rate at the end, effort rating and talk-test result (sentences, phrases or single words). If the third repeat is

much slower or your heart rate is far above your threshold range, you started too fast.

7. **Cool down and compare.** Jog easily 5–10 minutes. In your journal, compare your threshold pace with your 12-minute pace: threshold pace is usually somewhat slower. Write a weekly plan with one threshold workout, one interval or hill session and two or three easy runs.

Tips

- Even pacing gives the truest 12-minute result. Starting with a sprint usually means a slower total distance.
- Threshold workouts should feel controlled. If you are gasping, you are above threshold.
- Most endurance training should be easy; one threshold workout a week is plenty for most high-school runners.

Check your work

- ☐ I can explain VO₂ max, the Fick equation and the lactate threshold.
- ☐ I ran the 12-minute test and calculated my estimated VO₂ max, pace and heart-rate zones.
- ☐ I completed a threshold workout and matched heart rate, effort and the talk test.

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1. Record the 12-minute run: laps, meters, VO₂ max estimate, average pace and finishing heart rate, with every calculation shown.
2. Record the threshold workout in a table: repeat, distance, heart rate, effort and talk test.
3. Draw a graph of blood lactate against running speed, with a flat early section, the threshold and a steep climb; mark where your threshold workout and your 12-minute pace would fall.
4. Write the Fick equation and explain in your own words three ways training raises VO₂ max.

From history. Kenneth Cooper, an Air Force physician, developed the 12-minute run in the 1960s to test the fitness of thousands of airmen without laboratory equipment. In 1968 he published the formula relating 12-minute distance to measured VO₂ max, and his book *Aerobics* the same year made the word familiar to millions.

COMMON MISTAKES

- Thinking lactic acid causes next-day soreness. Lactate is cleared within an hour or so and is used as fuel; soreness comes from small muscle strains.
- Running every workout hard. Most aerobic training should be easy, with one or two harder sessions a week.
- Treating formula estimates as exact. HRmax and VO₂ max formulas are averages; use effort and the talk test too.
- Starting a time trial or threshold repeat too fast and slowing badly at the end.

Make it a game • Threshold Talk Test. Run or walk at a steady effort where you can barely speak a full sentence. Time yourself for ten minutes and record pulse every two. Explain lactate threshold, VO₂ max and running economy. Tell the Wasserman and Hill stories. Your parent checks your Fick equation: cardiac output times oxygen extraction. Retest later.

5.2 A RACE PLAN: 5K OR 10K

OBJECTIVES

- Tell how Billy Mills won the 1964 Olympic 10,000 meters, and what it shows about a race plan.
- Explain why even or slightly negative pacing is most efficient, using the lactate threshold.
- Predict a 5K time from a test with Riegel’s formula and write a race plan with splits, fueling and a warm-up.
- Run a rehearsal and a race, compare actual and planned splits, and lead a family fitness day.

Warm-up. Jog easily 5 minutes, then do leg swings, walking lunges, 20 seconds of skipping and 4 strides of about 80 yards, the last one at about your planned race pace. Think about it: in a race, is it better to run the first mile fast “while you are fresh,” or to hold back? What happened the last time you started too fast?

WATCH

Incredible Moment As Underdog Billy Mills Wins 10,000m Gold - Tokyo 1964 Olympics

Olympic Games · 3:55

<https://www.youtube.com/watch?v=5F5iCsymMj0>

WHEN TO WATCH

After the story paragraph. Watch where Mills runs in the pack and when he makes his move.

Note: Official Olympic footage of the 1964 10,000-meter final in Tokyo, in color.

BACKUP VIDEO

Pacing 101: Why You Need To Negative Split (and Why It's So Hard)

Fleet Feet · 7:49

<https://www.youtube.com/watch?v=3ap1QFvFmQ8>

Before you write your race plan, to hear a running coach explain positive, even and negative splits and how to practice them.

KEY TERMS

split

The time for one section of a race, such as each kilometer or mile.

even pacing

Running every section of a race at about the same speed, the most energy-efficient way to cover a distance.

negative split

Running the second half of a race faster than the first half.

race plan

A written plan for a race: goal time, splits, warm-up, fueling, where to make a move and what to do if things go wrong.

Riegel's formula

A prediction of race time from another distance: $T_2 = T_1 \times (D_2 \div D_1)^{1.06}$.

CORE IDEAS

The story. Billy Mills was raised on the Pine Ridge Reservation in South Dakota and was orphaned at 12. He ran at the Haskell Institute in Kansas and at the University of Kansas, then served as an officer in the U.S. Marine Corps. In the 10,000-meter final at the Tokyo Olympics on October 14, 1964, almost no one expected him to contend; he had never broken 29 minutes. The favorite was Australia's Ron Clarke, the world-record holder. Clarke pushed the pace, trying to break the field, but Mills stayed with the leaders. On the last lap, among slower runners being lapped, Mills was jostled and fell back, while Tunisia's Mohammed Gammoudi surged into the lead. On the final straight Mills swung wide into the outer lanes and sprinted past them both to win in an Olympic record of 28:24.4, nearly 50 seconds faster than his previous best.

How they figured it out. Mills had a plan: stay relaxed in the leading group, waste no energy on early surges, and keep enough in reserve for a final sprint. Exercise scientists studying world records from 5,000 meters to the marathon have found the same pattern Mills used: nearly every record was run at a very even pace, often with a slightly faster finish. Runners who start much faster than they can hold build up lactate and acidity above their threshold early and pay for it by slowing dramatically later. In 1981 an American engineer and marathoner, Peter Riegel, published a

simple formula that predicts race times from another race: $T_2 = T_1 \times (D_2 \div D_1)^{1.06}$. The exponent, slightly above 1, reflects that longer races must be run a little slower per kilometer.

How your body works. A 5K for a high-school runner lasts roughly 17 to 30 minutes, run at or a little above lactate threshold; a 10K is run close to threshold. If you begin well above that pace, lactate builds faster than it can be cleared, glycogen is used up faster, and breathing and muscles reach their limit before the finish. An even pace spreads the effort, so you reach the line with the most distance covered for the energy spent. A slightly faster last kilometer, when you can “spend it all,” is the best finish. Worked example: a student ran 2,400 meters in the 12-minute test. Riegel’s formula predicts 5,000 meters in $T_2 = 12 \times (5,000 \div 2,400)^{1.06} = 12 \times 2.083^{1.06} \approx 12 \times 2.18 \approx 26.1$ minutes, about 26:08, or about 5:14 per kilometer (8:25 per mile). A plan: first kilometer 5:18 (hold back), kilometers 2–4 at 5:14 each, last kilometer 5:08: 5:18 + 15:42 + 5:08 = 26:08.

Think it through. Scripture says, “let us run with patience the race that is set before us” (Hebrews 12:1). Patience in a race means holding back early so you can finish well, and the Christian life is like that too: faithfulness over the whole distance matters more than a fast start.

Try it. This week you will predict your 5K time, write a race plan, run a rehearsal at goal pace, and then run your race as the centerpiece of a family fitness day.

PICTURE STUDY



*Start of the 5,000 Metres Final, Stockholm Olympic Games, Unknown photographer, July 10, 1912 ·
Photograph · Stockholm Olympic Stadium, Sweden
Image: [Wikimedia Commons](#), public domain*

This photograph catches the start of the 5,000-meter final at the 1912 Olympics in Stockholm, a race won by Hannes Kolehmainen of Finland in a world record of 14:36.6 after a long duel with France's Jean Bouin. Some runners have burst away from the line; others start more steadily. In a race of more than 14 minutes, that first moment matters less than how each runner spends his energy over the next twelve and a half laps.

Look closely

- Look at the runners' first strides. Which ones seem to be sprinting, and which are starting more steadily?
- Find the puff of smoke behind them. What made it?
- Look at the crowd. What does it tell you about how important this race was?
- Look at the runners' shirts and emblems. What do they tell you about where the runners came from?

Talk about it

1. If a runner sprinted the first 200 meters of this 5,000-meter race, what would happen inside his muscles later in the race?

2. Kolehmainen won with a long, hard duel to the finish. How is that like Billy Mills's race?
3. What would your race plan say about the first kilometer?

Safety first. Run the rehearsal and race on a safe, measured route away from traffic, with water at the start and finish, an adult present and a plan for anyone who needs to stop. Choose a cool time of day, warm up and cool down, and stop at once at chest pain, dizziness or trouble breathing. Family members walk or run at their own pace; those with health concerns check with their doctor first.

ACTIVITY

The Race Plan and the Family Fitness Day

You will predict your time, write a complete race plan, rehearse it, and then run your race as part of a family fitness day that you plan and lead. Choose a 5K, or a 10K if you have been training for one; younger family members can do a shorter course.

You will need

- A measured course (a track, or a loop measured with a map app, with each kilometer or half-mile marked with chalk or cones)
- A stopwatch with a lap button, a clipboard and helpers to call out splits
- A water table, and a recovery meal or snack you help prepare
- Your fitness journal

Steps

1. **Predict (Session 1 or 2).** Use your 12-minute result from Lesson 5.1 (or a recent race) in Riegel's formula to predict your 5K (or 10K) time. Divide by the distance to find goal pace per kilometer and per mile.
2. **Write the race plan.** Include goal time and splits for every kilometer (a slightly slower first kilometer, even middle, slightly faster finish); your warm-up; your pre-race meal and timing (from Lesson 3.1); fluids (from Lesson 2.2); where you will start to push; and what you will do if you start too fast or a side stitch comes.
3. **Rehearsal (Session 2).** After the full warm-up, run 2 kilometers (or 1 mile) at exactly goal pace, checking your split at each marker. Rest 3 minutes, then run 400 meters at the pace you plan for the final kilometer. Record your splits, heart rate and effort, and adjust the plan if goal pace felt far too hard or too easy.
4. **Plan the family fitness day.** Write a schedule: your warm-up for everyone (from Lesson 1.2's 11+ running drills), the race (a full course for you and a shorter course or walk for others), a water table, a cool-down and stretch, a recovery meal you help cook (from Lesson 3.2), and a 3-minute talk you will give about one thing you learned this quarter.

5. **Session 3: race day.** Eat as planned, set up the course and water table, and lead the warm-up. Run your race to your plan while a helper records your splits. Cheer the others in.
6. **Compare.** Make a table of planned and actual splits for every kilometer and the difference for each. Did you run even, positive or negative splits? Where did you lose or gain time?
7. **Close the day.** Lead the cool-down, serve the meal, give your talk and thank everyone. Write a race report: what went to plan, what did not, and the goal for your next race.

Tips

- The first kilometer always feels easy. Trust your plan, not your excitement.
- Glance at your watch at each marker; small corrections early prevent big losses later.
- A family fitness day is about joy and encouragement. Celebrate every finisher, walking or running.

Check your work

- ☐ I can explain why even or negative pacing is most efficient and tell how Billy Mills won.
- ☐ I predicted my time, wrote a full race plan, rehearsed it and raced it.
- ☐ I planned and led a family fitness day and compared my planned and actual splits.

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1. Show your Riegel prediction step by step, your goal pace per kilometer and mile, and your planned splits.
2. Make a table of planned and actual splits, with differences, and a line graph of both.
3. Write your race report: what went to plan, what did not, how it felt and your next goal.
4. Write the family fitness day schedule and a list of who took part and what each person did.

From history. Billy Mills remains the only American man to have won the Olympic 10,000 meters. The next year he set a world record for six miles. His race is often called one of the greatest upsets in Olympic history, and in later years he spent much of his time encouraging young people on reservations across the country.

COMMON MISTAKES

- Starting too fast. A first kilometer even 15–20 seconds faster than goal pace often costs much more time later.
- Trying something new on race day: new shoes, a new food or a new drink.
- Skipping the warm-up before a 5K. A short race needs a good warm-up so the body is ready for race pace.
- Judging the race only by the finishing time. Pacing, effort and following your plan matter too.

Make it a game • Race Plan Prediction. Predict your 5K time with Riegel's formula from a recent mile. Then plan splits for even and negative pacing. Tell Billy Mills's last lap in Tokyo. Your parent plays a coach who asks why not start fast. Run a trial mile at the planned pace and compare. Smallest gap wins.

Scripture. “let us run with patience the race that is set before us” (Hebrews 12:1, KJV)

A good race is run with patience from the start to the finish. So is the life of faith.

AEROBIC TRAINING

Two numbers explain much of endurance: how much oxygen your body can use at most (VO₂ max) and how close to that ceiling you can work before fatigue builds quickly (the lactate threshold). In 1923 the British physiologist A. V. Hill described the first; in 1964 the American physician Karlman Wasserman, measuring the breathing of heart patients on exercise machines, described a “threshold” that became the second. In this unit you will learn how oxygen delivery and use set VO₂ max, what really happens to lactate in hard exercise, and why threshold training is the heart of endurance. You will estimate your VO₂ max with Kenneth Cooper’s 12-minute run and do a threshold workout.

Then you will plan and run a race. On October 14, 1964, at the Tokyo Olympics, a little-known U.S. Marine lieutenant named Billy Mills, who had never run 10,000 meters faster than 29 minutes, stayed with the leaders and then sprinted past them on the final straight to win in an Olympic-record 28:24.4. You will learn the science of pacing, predict your own 5K time from your test, write a race plan with splits, run it, and lead your family in a fitness day to close the quarter.

PREREQUISITES

- Knows aerobic and anaerobic energy, heart rate, stroke volume and cardiac output (earlier grades)
- Can find a pulse, use an effort rating and do interval training
- Can work with formulas, decimals, exponents on a calculator and minutes-and-seconds arithmetic

MASTERY CHECKLIST

- ☐ I can explain VO₂ max and what limits it, using the Fick equation in words.
- ☐ I can explain lactate threshold, what lactate really is and why threshold training improves endurance.
- ☐ I can estimate VO₂ max from a 12-minute run and estimate heart-rate training zones.
- ☐ I can predict a race time, plan even or negative splits and pace a race.
- ☐ I can plan and lead a family fitness day.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A heart-rate monitor or sports watch:** Optional, for the threshold workout and race. Counting your pulse for 15 seconds right after each repeat works well too.
- **A stopwatch with a lap button:** Optional; a phone timer does the same job for the 12-minute run, the threshold repeats and race splits.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

5.1 Lactate Threshold and VO₂ Max

3 sessions of 45–50 minutes

5.2 A Race Plan: 5K or 10K

3 sessions of 45–50 minutes

UNIT 5 REVIEW

Answer each question. Show your work for every calculation. The review is worth 100 points.

1. **8 pts**

What did A. V. Hill and Hartley Lupton discover in the 1920s, and what did Karlman Wasserman describe in 1964?

2. **8 pts**

Write the Fick equation in words and name three training adaptations that raise VO₂ max.

3. **8 pts**

Explain what happens to blood lactate as running speed increases, and define the lactate threshold.

4. **6 pts**

Is lactate a waste product that causes next-day soreness? Explain.

5. **10 pts**

A student runs 2,750 meters in Cooper's 12-minute test. Estimate her VO₂ max with $VO_2 \text{ max} \approx (d - 504.9) \div 44.73$, and find her average pace per kilometer.

6. **8 pts**

Estimate the maximum heart rate of a 17-year-old with $HR_{max} \approx 208 - 0.7 \times \text{age}$, and a threshold range of 85–90 percent of it.

7. **8 pts**

Describe Billy Mills's 1964 Olympic 10,000-meter race and the plan that helped him win.

8. **8 pts**

Why do world records from 5,000 meters to the marathon tend to be run at even pace? Use the lactate threshold in your answer.

9. **10 pts**

Using Riegel's formula $T_2 = T_1 \times (D_2 \div D_1)^{1.06}$, predict a 10K time for a runner who ran 5K in 24:00. (Use $2^{1.06} \approx 2.085$.)

10. **10 pts**

A runner planned 5K splits of 5:20, 5:15, 5:15, 5:15, 5:10. Her actual splits were 5:00, 5:12, 5:25, 5:35, 5:30. Find the planned and actual totals and the difference. What kind of split did she run, and what was her likely mistake?

11. **6 pts**

List four parts of a complete race plan.

12. **10 pts**

In four to six sentences, explain how Hebrews 12:1 and the science of pacing fit together, and describe the family fitness day you led.

ANSWER KEY

1. Hill and Lupton found that oxygen use rises with running speed until it levels off at a maximum, the maximum oxygen intake ($\text{VO}_2 \text{ max}$). Wasserman, testing heart patients, found the point where breathing rises faster than oxygen use and blood lactate begins to climb, which he called the anaerobic threshold (now lactate threshold).
2. $\text{VO}_2 = \text{cardiac output (stroke volume} \times \text{heart rate)} \times \text{oxygen extraction (arterial minus venous oxygen content)}$. Adaptations: larger stroke volume, more blood volume, more capillaries, more mitochondria (any three).
3. At easy speeds lactate stays near resting levels (about 1 mmol/L) because it is cleared as fast as it is produced; as speed rises, production eventually exceeds clearance and lactate climbs steeply. The lactate threshold is the intensity above which lactate builds up faster than it can be cleared, so fatigue comes much sooner.
4. No. Lactate is a fuel, carried to the heart, other muscles and the liver and used for energy (George Brooks's lactate shuttle); it is cleared within about an hour after exercise. Next-day soreness comes from small strains in muscle fibers.
5. $(2,750 - 504.9) \div 44.73 = 2,245.1 \div 44.73 \approx 50.2 \text{ mL/kg/min}$. Pace: $12 \text{ min} \div 2.75 \text{ km} \approx 4.36 \text{ min/km} \approx 4:22 \text{ per km}$.
6. $208 - 0.7 \times 17 = 208 - 11.9 = 196.1 \approx 196 \text{ bpm}$. 85% $\approx 167 \text{ bpm}$; 90% $\approx 176 \text{ bpm}$. Threshold range about 167–176 bpm.
7. Mills, a little-known Marine officer who had never broken 29 minutes, stayed relaxed with the leaders while Ron Clarke pushed the pace; on the last lap he was jostled and fell back as Gammoudi surged, then swung wide on the final straight and sprinted past both to win in an Olympic record 28:24.4. His plan: stay with the leaders, avoid wasting energy, save a final sprint.
8. Running much faster than sustainable early pushes the runner well above lactate threshold, so lactate and acidity build and glycogen is used fast, forcing a large slowdown later; even pacing keeps effort near threshold and spends energy most efficiently, with a slight surge only at the end.
9. $T_2 = 24 \times 2^{1.06} \approx 24 \times 2.085 \approx 50.04 \text{ min} \approx 50:02$. Pace about 5:00 per km.
10. Planned: $5:20 + 5:15 \times 3 + 5:10 = 5:20 + 15:45 + 5:10 = 26:15$. Actual: $5:00 + 5:12 + 5:25 + 5:35 + 5:30 = 26:42$. She was 27 seconds slower than planned. A positive split: she started 20 seconds too fast, went above threshold and slowed badly.

11. Any four: goal time; splits per kilometer or mile; warm-up; pre-race meal and timing; fluids; where to push; what to do if starting too fast or if a problem comes; cool-down.
12. Answers vary. Full credit for: Hebrews 12:1 calls us to run with patience, and pacing science shows that holding back early and running evenly gives the best race; patience and faithfulness over the whole distance matter in training and in life; a clear description of the fitness day (warm-up, race, water table, meal, talk) and what the student learned.

UNIT CHALLENGE: MY RACE AND OUR FAMILY FITNESS DAY

Present your aerobic training and race. Include your 12-minute test and VO₂ max estimate, your threshold workout, a two-week training plan leading to your race (one threshold session, one interval session and easy runs each week), your race plan with predicted splits, your rehearsal, your planned and actual race splits with a graph, your race report, and the family fitness day schedule with a note from a parent. Finish with a one-page reflection on the whole quarter: what you learned about caring for the body God gave you, and the habits you will keep.

LOOK FOR	WHAT IT MEANS
Sound training	A two-week plan with mostly easy running, one threshold and one interval session a week, and the sessions logged with heart rate and effort.
Accurate prediction and plan	Riegel prediction, goal pace and planned splits calculated correctly, with a complete race plan.
Race execution and analysis	Planned and actual splits compared with differences and a graph, and an honest race report.
Family fitness day	A clear schedule, a warm-up the student led, a water table and recovery meal, and a parent's note on how it went.
Quarter reflection	A page connecting sleep, hydration, nutrition, strength and aerobic training, judged on effort, honesty and improvement, not on the size of the numbers.