Index

Note: an asterisk marks a parameter whose definition may be found in the glossary pages 204–210

acetyl-CoA, formation 3
acidosis, chronic metabolic, ventilatory threshold, respiratory compensation point reduction 127–128
adenosine triphosphate (ATP) regeneration
aerobic metabolic pathways 6
cellular energy deprivation 5
NH3 derivation 144
aerobic capacity, submaximal testing 51
aerobic metabolism, exercise physiology 5–6
aerobic performance
data analysis 154
four-panel displays 159
African males/females, nomograms of lung function 229
AIDS, XT relative contraindication 88
Allen test, modified, arterial blood sampling 49
alveolar air equation 138
alveolar slope, PaO2, and Paco2 137, 138, 140
alveolar-arterial oxygen partial pressure difference (Paw−PaO2) 138–139
definition, derivation, equation, and measurement units 138, 205
normal/abnormal response 138–139
American Heart Association, ECG specifications 46
American Heart Association/American College of Sports Medicine (ACSM)
Exercise Specialist certification 83
pro forma, preparticipation screening for XT 253
XT supervision 83
ammonia (NH3) 144
arterial blood sampling 48
definition, derivation, and measurement units 144
myopathy evaluation 73
normal/abnormal response 144
anaerobic metabolism, exercise physiology 5–6
anaerobic threshold see metabolic threshold
anemia, impaired oxygen delivery 168
aneurysms, XT relative contraindication 87–88
angina
CXT 73
XT termination 88–89, 89
anxiety
cardiocirculatory response pattern abnormalities 165, 167
diagnosis 11, 12
exercise prescription 12
rapid shallow breathing association 173
sinus tachycardia 113
symptom perception abnormalities 178
aortic aneurysm, XT contraindication 87
appendices 204–263
arm ergometers 31–32
calibration, accuracy, and precision 31
maintenance 32
maximal incremental work rate 82
oxygen cost 212
settings 78
submaximal incremental work rate 64–65
arterial blood gas tensions (PaO2, and Paco2) 135–137
oxygen tension, defined 207
arterial blood sampling 48–50
arterial catheter 49, 71
calibration, accuracy, and precision 49–50
description, and operational principles 48–49
double arterial puncture 49
laboratory tests 71
maintenance 50
modified Allen test 49
oxygen saturation (Spo2), pulse oximetry 47
Paco2 determination, hyperventilation, and dead space increase 135
arterial pressure see blood pressure
arterial–end-tidal carbon dioxide partial pressure difference (Paw−Paco2) 139–141
defined 207
definition, derivation, and measurement units 139–140
normal/abnormal responses 140–141
arteriovenous difference in oxygen content* definition, derivation, and measurement units 115–116, 205
normal/abnormal response 116
arthritis, symptom perception abnormalities 178
assessment
  case studies
    for exercise program 185–7
    for pulmonary rehabilitation 191–195
asthma
  case study 181–5
  exercise-induced (EIA), CXT 71–73
  ventilatory flow limitation 134
  ventilatory limitation 169
  see also pulmonary disease
  Åstrand–Ryhming cycling test 65
  Åstrand–Ryhming nomogram of lung function 227
ataxia, XT termination 88–89
atrial contractions, see premature atrial contractions
atrial fibrillation
  cardiovascular response pattern abnormalities 167
  ECG 113, 114
  XT termination 89
Balke treadmill protocol 64, 78–79, 214, 241–242
basic life support (BLS), training, and certification 89
beta-sympathomimetic antagonists
  cardiovascular response pattern abnormalities 167
  fβ-max reduction 109
biological variability, means 140, 159
biomechanical efficiency, physical training 151
blood doping, oxygen delivery increase 168
blood pressure (BP)
  diastolic, XT termination 88–89
  mean, equation 119
measurement
  intraarterial 47
  procedures 244
  resting 76
  sphygmomanometry 44–47
monitor 84
systemic arterial pressure 119–121
  definition 206
  definition, derivation, and measurement units 119–120
  normal/abnormal response 120–121
  oxygen uptake relationship 120
  systolic, XT termination 88–89
BLS see basic life support
  “blue bloaters”, lung disease 125–126
Bohr equation 2, 124
V′′/V′, 141
Borg scale for perceived exertion (psychometric scale) 256
bradycardia, sinus, ECG 113
breath-by-breath systems 45–46
averaging method 97–98
  calibration, accuracy, and precision 45
  description, and operational principles 45
  maintenance 45–46
breathing, rapid shallow, ventilatory control abnormalities
  173
breathlessness*, 146–147
  definition, derivation, and measurement units 146, 205
  exertional, case study 187–191
  normal/abnormal response 146–147
  visual analog scale 146, 258
bronchitis, chronic
  ventilatory flow limitation 134, 169
  see also pulmonary disease
bronchoconstriction test 71–73
bronchospasm, exercise-induced (EIB), CXT 71–73
Bruce treadmill protocol 78–79, 214–215, 242
cardiac exercise testing 73
  data table 64
CABG (coronary artery bypass grafting) 11, 13
calcium channel antagonists
  cardiovascular response pattern abnormalities 167
  fβ-max reduction 109
calculations 211–219
carbon dioxide
  analyzers 42
  calibration, accuracy, and precision 42
  maintenance 42
  production, defined 96–97
  tension, arterial, regulation 2
  see also arterial blood gas tensions; end-tidal gas tensions;
  pulmonary gas exchange
carbon dioxide output*
  calculation 216
  defined 96–97, 208
  ventilatory coupling 2
carboxyhemoglobinemia, impaired oxygen delivery 168
cardiac failure
  oscillating ventilation 173
  see also congestive heart failure
cardiomyopathy, cardiovascular response pattern
  abnormalities 167
cardiac output*
  116–118
  cardiovascular coupling 2
  definition, derivation, and measurement units
  116–117
  instantaneous oxygen uptake equation 117
  normal/abnormal response 117–118
cardiac rhythm
ECG abnormalities 114
XT termination 88–89
cardiac stroke volume (SV) 118–119
calculation 118
definition, output, and \( f_j \) association 2
defined 208
definition, derivation, and measurement units 118
estimation 119
incremental exercise 111
maximal exercise 112
normal/abnormal response 118–119
cardiac XT 73
cardiomyopathy

differential diagnosis 11
impaired oxygen delivery 169
SV reduction 118
cardiopulmonary coupling, external work rate 2
cardiopulmonary XT, supervision 83
cardiorespiratory fitness
classification 230–238
see also oxygen uptake, maximum
cardiovascular disease

cardiovascular limitation 164
cardiovascular response pattern abnormalities 164–166
differential diagnosis 9–10
disease progression/regression assessment 151–152
exercise prescription 12
impaired oxygen delivery 168–169
NYHA classification 99–100, 112
oxygen pulse response patterns 112
oxygen uptake, prolonged 105
shunt abnormalities

arterial blood gas tension abnormalities 136
gas exchange abnormalities 175
valvular
slope of cardiovascular response 111
SV reduction 118
XT relative contraindication 88
Weber classification 99–100
SV values 119
cardiovascular efficiency

oxygen pulse 111–112
slope of cardiovascular response 110–111
cardiovascular limitation 8, 10
data analysis 154
four-panel displays 159–161
nine-panel displays 159
diagnostic response patterns 162–167
cardiovascular response

abnormalities, diagnostic response patterns 164–167
four-panel display 159, 161
slope 110–111
carnitine palmitoyl transferase (CPT) deficiency, muscle metabolism abnormalities 176

case studies

assessment in preparation for exercise program 185–187
assessment for pulmonary rehabilitation 191–195
asthma 181–5
muscle fatigue, and exertional breathlessness 187–191, 199–203
occupational exposure to solvents 195–199
catheter, arterial, arterial blood sampling 49, 71

cellular energy generation

equations 3
metabolic substrates 7

cellular respiration coupling, external work rate 1–2
central nervous system symptoms, XT termination 89
chest wall compliance, reduced, ventilatory capacity reduction 124
chronic fatigue syndrome, muscle metabolism abnormalities 176–177
chronic obstructive pulmonary disease
6-minute walking test 95
abnormal symptom perception 177–178
case study 191–195
diagnostic XT 58
stair-climb 70
chronometers 19–20
chronotropic incompetence

cardiovascular response pattern abnormalities 165, 167
\( f_{\text{max}} \) reduction 109–110
citric acid cycle see Krebs cycle
clammy skin, XT termination 88–89
clinical exercise testing (CXT) 6–8, 67–74

clinical testing 204
field tests 68–70
laboratory tests 70–74
physician supervision 83
purposes, setting, and protocols 51, 52
submaximal testing 51
ventilatory capacity determination 76
see also diagnostic XT
clinical medical history questionnaire 253
clocks see chronometers
cold skin, XT termination 88–89

collection bags see gas collection bags
confidence interval, standard deviation of the mean 150
congenital heart disease, SV reduction 9–10
congestive heart failure

slope of cardiovascular response 111
XT contraindication 87
consent, informed 74–75, 250
contractile coupling 2
contraindications to XT 87–91
absolute 88
relative absolute 88
conversion constants 217–219
## Index

Cooper distance measurements
- walking and running tests 237–238
- 1.5-mile run 237
- 3-mile walk 238
Cooper tests 56, 57, 60
- estimation of maximum oxygen uptake 213, 239
- fitness categories 230, 232–233
coronary artery bypass grafting (CABG) 11, 13
coronary artery disease
- impaired oxygen delivery 169
- screening 11
- slope of cardiovascular response 111
- SV reduction 118
see also cardiovascular disease
counters 20
CPT see carnitine palmitoyl transferase
CR10 scale 145
crash cart, detailed contents 247–248
CWR see work rate tests, constant
CXT see clinical exercise testing
cyanosis, XT termination 88–89
cycle ergometers 21–27
- calibration, pre-XT 78
- concerns 23–25
description and operational principles 21–25
- electrically braked 23
- calibration, accuracy, and precision 27
- maintenance 27
- PWCl70 test 23
field exercise testing (FXT) 60, 234–235
- friction-braked 23
- leg, advantages and disadvantages 25
- maximal tests, work rate increments 79–80
- mechanically braked 21–23
- calibration, accuracy, and precision 25–27
- counters 20
- maintenance 27
- r.p.m. error effects 22–23
Monark, calibration 245
- oxygen cost 211
protocol pro forma 254
- settings 77–78
Storer cycle test, estimation of maximum oxygen uptake 214
submaximal constant work rate tests, Åstrand-Ryhming test 65
submaximal incremental work rate tests 61–63
- branching protocol 61
- $f_r$, blood pressure, and RPE timing 61, 63
YMCA multistage 61, 63
Wingate test 25
data integration and interpretation 85–87, 149–179
data displays 152–162
- graphical
- four-panel 159–161
- nine-panel 158, 168
- recommended 78, 79
- sequential, trending phenomena 161–162, 165
- tabular 155–157, 168
- multiple data
- diagnostic response patterns 162–179
- reduction and display 152–162
- single variables
- reference value comparison 149–150
- serial measurements 151–152
technical factors 152–154
death space
- calculation, CXT 71
gas exchange abnormalities 173
- $P_{vco_2}$ increases 140
- $P_{vco_2}$ and $P_{vo_2}$ influence 137–138
- ventilatory equivalents 135
dead space–tidal volume ratio ($V_d/V_t$) 2, 141–142
age effects 142
- Bohr equation 141
defined 208
definition, derivation, and measurement units 141–142
- normal/abnormal response 142
- ventilatory requirement 126
definitions, glossary 205–210
denial, symptom perception abnormalities 178
diabetes mellitus, XT relative contraindication 88
diagnostic exercise test (CXT: diagnostic) 8, 68
case studies
- asthma 181–185
- breathlessness and fatigue 187–191, 199–203
- chronic obstructive pulmonary disease 58, 191–195
- progress monitoring 68
- termination 89
dietary recommendations, lung disease 126
differential diagnosis 9–11
diffusion impairment, $P_{vco_2}$ 139
digoxin
- cardiovascular response pattern abnormalities 167
diastolic reduction 109
diltiazem, $F_{RR}$ reduction 109
disability evaluation 9, 11, 12
Duglas bag technique, gas collection 32–35, 43
dynamic hyperinflation, tidal flow-volume loop 134
dyspnea see breathlessness
dysrhythmias
- cardiovascular response pattern abnormalities 165–167
- CXT risk assessment 68
- ECG 114, 115
- exercise prescription 12
- XT termination 89
ECG see electrocardiography

effort

suboptimal

conscious/subconscious

data analysis, nine-panel display 156–157, 179

definition and identification 178–179

EIA see asthma, exercise-induced

EIB see bronchospasm, exercise-induced

EILV see end-inspiratory lung volume
electrocardiogram (ECG) 46

American Heart Association specifications 46

calibration, accuracy and precision 46

definition, derivation, and measurement units 112–113, 205
dysrhythmias 114–115

maintenance 46

monitoring failure, XT termination 89

normal response 113–114

resting 12-lead 75

electrode placement 75, 76

skin preparation 75

technician 84

asthma, exercise-induced

bronchospasm, exercise-induced

end-inspiratory lung volume

electrochemical or fuel cell analyzers, oxygen analyzers 39

electro transport chain see mitochondrial pathway

Ellestad protocol, cardiac exercise testing 73

Embden–Meyerhof pathway 3–4

emergency procedures 89–91

crash cart
detailed contents 247–248

drugs 248

emergency response board 90

resuscitation equipment 90–91

emphysema 13

cardiovascular response pattern abnormalities 166

gas exchange abnormalities 173–174

see also pulmonary disease

dead space in

end-inspiratory lung volume (EILV), VT relationship 133

dysrhythmias 114–115

definition, derivation, and measurement units 112–113, 205

data analysis, nine-panel display 156–157, 179

definition and identification 178–179

EIA see asthma, exercise-induced

EIB see bronchospasm, exercise-induced

EILV see end-inspiratory lung volume
electrocardiogram (ECG) 46

American Heart Association specifications 46

calibration, accuracy and precision 46

definition, derivation, and measurement units 112–113, 205
dysrhythmias 114–115

maintenance 46

monitoring failure, XT termination 89

normal response 113–114

resting 12-lead 75

electrode placement 75, 76

skin preparation 75

technician 84

asthma, exercise-induced

bronchospasm, exercise-induced

end-inspiratory lung volume

electrochemical or fuel cell analyzers, oxygen analyzers 39

electro transport chain see mitochondrial pathway

Ellestad protocol, cardiac exercise testing 73

Embden–Meyerhof pathway 3–4

emergency procedures 89–91

crash cart
detailed contents 247–248

drugs 248

emergency response board 90

resuscitation equipment 90–91

emphysema 13

cardiovascular response pattern abnormalities 166

gas exchange abnormalities 173–174

see also pulmonary disease

dead space in

end-inspiratory lung volume (EILV), VT relationship 133

dysrhythmias 114–115

definition, derivation, and measurement units 112–113, 205

data analysis, nine-panel display 156–157, 179

definition and identification 178–179

EIA see asthma, exercise-induced

EIB see bronchospasm, exercise-induced

EILV see end-inspiratory lung volume
electrocardiogram (ECG) 46

American Heart Association specifications 46

calibration, accuracy and precision 46

definition, derivation, and measurement units 112–113, 205
dysrhythmias 114–115

maintenance 46

monitoring failure, XT termination 89

normal response 113–114

resting 12-lead 75

electrode placement 75, 76

skin preparation 75

technician 84

asthma, exercise-induced

bronchospasm, exercise-induced

end-inspiratory lung volume

electrochemical or fuel cell analyzers, oxygen analyzers 39

electro transport chain see mitochondrial pathway

Ellestad protocol, cardiac exercise testing 73

Embden–Meyerhof pathway 3–4

emergency procedures 89–91

crash cart
detailed contents 247–248

drugs 248

emergency response board 90

resuscitation equipment 90–91

emphysema 13

cardiovascular response pattern abnormalities 166

gas exchange abnormalities 173–174

see also pulmonary disease

dead space in
Index

exercise testing (XT) (cont.)
- methods 51–92
  - maximal vs submaximal 51–54
- nomenclature 7–8
- optimal protocol selection 83–85
- physical fitness assessment 8–9
- preparation, pro forma 254
- preparticipation screening 253
- purpose 1–14
- report generation 86
- response variables 93–148
- safety considerations 87–91
- subject preparation 74–77
- termination indications 88
- see also clinical exercise testing (CXT); performance exercise testing (PXT)
- exercise tolerance, evaluation 9
- exertional breathlessness, case studies 187–191, 199–203
- expiratory flow-volume relationships
  - defined 206
  - see also inspiratory/expiratory flow external work
- fatigue
  - XT termination 88–89
  - see also chronic fatigue syndrome
  - heart rate
    - \( f_h \) see heart rate
  - \( f_{\text{max}} \) see heart rate, maximum
- Fick equation 2, 110, 111
- field exercise testing (FXT)
  - CXT 68–70
  - cycle test 60, 235
  - defined 4
  - PXT 55–60
  - run tests 56–58
  - step tests 58–60
  - swim test 60, 236
  - walking tests 55–56
- fitness assessment
  - categories, AHA, Åstrand and Cooper tests 232–235, 238–239
  - CWR tests 65
  - field tests 55–60
  - laboratory tests 62
  - see also performance exercise testing (PXT)
- flow and volume transducers 36–38
  - calibration, accuracy and precision 38
  - description and operational principles 36–38
  - hot-wire anemometer 38
  - maintenance 38
  - Pitot tube 37–38
- pneumotachograph 37
  - turbine transducer 38
- force, conversion constants 217
  - forced expired volume in 1 second \( (\text{FEV}_1) \) 35
  - nomograms 228–229
  - ventilatory capacity estimation 123, 124
  - \( f_h \) see respiratory rate
- gait problems, XT termination 89
  - gas analyzers 39–43
  - blood sampling 49–50
  - carbon dioxide analyzers 42
  - mass spectrometry 42–43
  - oxygen analyzers 39–42
  - water vapor pressure 41
  - gas collection bags 32–35
  - Douglas bag technique 32–35
  - maintenance 34–35
  - meteorological balloons 32, 34
  - gas exchange
    - data analysis 154–155, 159
    - four-panel displays 160–161, 163
    - nine-panel displays 158, 173
    - disorders, differential diagnosis 117
    - impaired
      - data analysis, nine-panel display 156–157, 173
      - diagnostic response patterns 173–175
      - mechanisms, \( P_{a-a}O_2 \) 139
    - gas exchange threshold see metabolic threshold
    - gas volumes, standardized, calculation 215–216
    - gasometers see spirometers and gasometers
    - general gas law 215
- glossary
  - exercise testing 204
  - physiological variables 205–210
  - glycolysis, anaerobic 3–4
- Haldane equation 128
- Harbor–UCLA Medical Center, nine-panel graphical displays 157–158
- heart block, ECG 114
- heart rate \( (f_h) \)
  - age-related decline 109
  - cardiovascular response 2
  - defined 205
  - medication 166–167
  - oxygen uptake relationship 110
  - RPE relationship 145
  - treadmill and cycle exercise comparisons 24
  - heart rate, maximum \( (f_{\text{max}}) \) 109–110
  - definition, derivation, and measurement units 109
  - equation 109
  - normal/abnormal response 109–110
  - standard deviation 150
heart transplantation 11, 13
Henderson–Hasselbalch equation, bicarbonate calculation 135
hepatitis, XT relative contraindication 88
high-energy phosphates 2
hot-wire anemometer, flow and volume transducers 38
hypertension
arterial systolic pressure increase relationship 120
cardiovascular response pattern abnormalities 164–166
CXT risk assessment 68
exercise prescription 12
pulmonary
gas exchange abnormalities 174–175
$P_{aw}$ increase 121
hyperthyroidism, cardiovascular response pattern abnormalities 167
hyperventilation
acute, ventilatory control abnormalities 172
diagnosis 11, 12
extreme, ventilatory limitation 170
$f_{r}$ increase 130
$R$ adverse factor 107
ventilatory equivalents 135
$V_{e}$ abnormal responses 129
hyperventilation syndrome 11
ventilatory control abnormalities 172
hypokalemia, XT relative contraindication 88
hypomagnesemia, XT relative contraindication 88
hypotension, exercise prescription 12
hypoventilation, ventilatory control abnormalities 172–173
hypoxemia
CXT risk assessment 68
exercise prescription 12
oxygen uptake kinetics, cardiovascular and pulmonary
disease 105
$P_{pa}$ increase 121–122
$I/E$ ratio see ratio of inspiratory to expiratory time ($T_{i}/T_{e}$)
ILD see interstitial lung disease
illustrative cases and reports 181–203
incremental exercise protocols 66–67
indoor courses 18
infection
acute, XT contraindication 87
chronic, XT relative contraindication 88
informed consent 240
pretest subject preparation 74–75
inspiratory/expiratory flow–volume relationships* 133–134
defined 206
definition, derivation, and measurement units 133
normal/abnormal response 133–134
inspiratory/expiratory time ratio ($T_{i}/T_{e}$) 131–133
definition, derivation, and measurement units 131, 207
normal/abnormal response 131–133
instrumentation 15–50
interstitial lung disease (ILD), gas exchange abnormalities
173–174
isowork analysis, physical training 151
Joint Commission for the Accreditation of Hospital
Organizations (JCAHO), clinical standards 87
Korotkoff sounds, tonal quality and interpretation 139
Krebs cycle 3–4
LA see lactate
laboratory exercise testing (LXT) 60–67
CXT 70–74
with/without arterial blood sampling 70–71
defined 204
fitness assessment 62
PXT 60–67
work rate tests
maximal incremental 66–67
submaximal constant 65–66
submaximal incremental 61–65
lactate (La) 142–144
arterial blood gas tensions 136
blood concentrations, treadmill and cycle exercise
comparisons 24
definition, derivation, and measurement units 142–143
metabolic threshold 143
metabolism
arterial blood sampling 48
exercise prescription 12
myopathy evaluation 73
normal/abnormal response 143–144
ventilatory control abnormalities 128
laser diode absorption spectroscopy (LDAS), oxygen analyzers 40
LED see light-emitting diode
leg cycle ergometers see cycle ergometers, leg
leg cycling, oxygen cost 211
lifestyle modifications 12, 13
PXT 8
light-emitting diode (LED), pulse oximetry 47
lightheadedness, XT termination 88–89
lung function, nomograms 123, 150, 228–229
lung volume reduction surgery (LVRS) 11, 13
LVRS see lung volume reduction surgery
McArdle’s syndrome
La levels 143
metabolic threshold, abnormal response 103
muscle metabolism abnormalities 175–176
$R$ values 107
malingering
diagnosis 11, 12
symptom perception abnormalities 178
Index

272

mass spectrometry 42–43
calibration, accuracy and precision 42
description and operational principles 42
maintenance 43
maximum minute ventilation (MMV)* 122–124
definition, derivation, and measurement units 122–123
$V_e$ changes 2
normal/abnormal response 123–124
maximum oxygen uptake see oxygen uptake, maximum*
maximum voluntary ventilation (MVV)*
defined 206
measurement 35, 123
measured courses 18–19
indoor 18
outdoor 19
measurement concepts 15–18
accuracy 16
calibration 16
error 17–18
precision 16
validation 16
mechanical coupling 2
medical history
multiple data analysis 152–153
questionnaire, pretest preparation 74
medication
cardiovascular limitation effects 164
cardiovascular response pattern abnormalities 165–167
ergogenic drugs 11, 13
metabolic cart operator 85
metabolic disease, XT relative contraindication 88
metabolic measurement systems 43–46
breath-by-breath method 45–46
mixing chamber method 43–45
metabolic pathways 3–4
ATP regeneration 6
exercise physiology 3–5
metabolic substrates, energetic properties 7
metabolic threshold*
data analysis 159
definition, derivation, measurement units 101–102
equations 230–231
lactate accumulation 143
normal response 102–103
interpretation 102–103
oxygen and carbon dioxide uptake relationship 103
physical fitness assessment 8–9
terminology 102
ventilatory equivalents and end-tidal gas tension
relationships 103–104
metabolism
aerobic and anaerobic 5–6
meteorological balloons
gas collection 32
calibration 34
metoprolol, $f_{310}$ reduction 109
metronomes 20–21
mitochondrial myopathy, NH3 increase 144
mitochondrial pathway
oxidative phosphorylation 3–5
schematic representation 5
mixing chambers
calibration, accuracy and precision 44
maintenance 45
metabolic measurement 43–45
Monark cycle ergometer, calibration 245
mononucleosis, XT relative contraindication 88
muscle diseases, differential diagnosis 11
muscle fatigue and exertional breathlessness, case studies
187–191, 199–203
muscle metabolism
abnormalities, diagnostic response patterns 175–177
data analysis 155
definition and identification 175
nine-panel display 156–157
muscle oxygen consumption*, oxygen delivery effectiveness
1–2
muscle respiratory quotient (RQmus) 107–109
calculation 108
definition, derivation, and measurement units 107–108, 207
normal/abnormal response 108–109
oxygen–carbon dioxide uptake relationship 108
muscle work*, conversion, external work 2
musculoskeletal disease, symptom perception abnormalities 178
musculoskeletal disorders, XT relative contraindication 88
musculoskeletal limitations 8, 10
MVV see maximum voluntary ventilation
myalgia, differential diagnosis 11
myoadenylate deaminase deficiency
muscle metabolism abnormalities 176
NH3 levels 144
myocardial dysfunction, slope of cardiovascular response
111
myocardial infarction
XT contraindication 87
XT termination 89
myocardial ischemia
CXT 73
CXT risk assessment 68
ECG 114–115, 116
exercise prescription 12
treadmill protocols 9
myocarditis, XT contraindication 87
myopathy 203
cardiac output 117–118
CXT evaluation 73

© in this web service Cambridge University Press

www.cambridge.org
### Differential Diagnosis
- Mitochondrial, muscle metabolism abnormalities 176
- NH₃ increase 144
- Slope of cardiovascular response 111
- Myophosphorylase deficiency
- Metabolic threshold, abnormal response 103
- R values 107
- Myxedema, XT relative contraindication 88
- Naughton protocol, cardiac exercise testing 73
- Nausea, XT termination 88–89
- Neurological symptoms, XT termination 89
- Neuromuscular disorders, XT relative contraindication 88
- New York Heart Association (NYHA) cardiovascular disease classification 99–100
- SV values 119
- NH₃ see ammonia
- Nitrogen concentration, expired, equation 128
- Noise, random errors 17
- Nomograms
  - FEV₁ estimation 123
  - Lung function 228–229
  - Prediction values 150
- Nutrition
  - Modifications 11, 13
  - See also carbohydrate
- Obesity, maximum oxygen uptake complications 99–100
- Occupational exposure to solvents, case study 195–199
- Ohio spirometer 36
- Operative risk, assessment by exercise testing 240
- Outdoor courses 19
- Oxygen, see also arterial blood gas tensions; end-tidal gas tensions; gas exchange; pulmonary gas exchange
- Oxygen analyzers 39–42
- Calibration, accuracy and precision 40–41
- Scholander procedure 40
- Water vapor 41
- Description and operational principle 39–40
- Electrochemical or fuel cell 39
- Laser diode absorption spectroscopy (LDAS) 40
- Maintenance 41–42
- Paramagnetic 39
- Zirconium oxide 39–40
- Oxygen breath* 130–131
  - Definition, derivation, and measurement units 130, 209
  - Equation 130
  - Normal/abnormal responses 130–131
- Oxygen consumption
  - Defined 96–97
  - Muscle* 1–2
- Oxygen content see arteriovenous difference in oxygen content
- Oxygen cost of exercise 211–213
- Oxygen delivery
- Impaired
  - Data analysis, nine-panel display 156–157, 168
  - Definition and identification 167–168
  - Diagnostic patterns 167–169
- Oxygen partial pressure
  - Alveolar, increase 138
  - Mixed venous, reduction 138
  - Reference values, arterial blood and alveolar-arterial difference 139
- Oxygen pulse* 111–112
  - Definition, derivation, and measurement units 111–112, 209
  - Equation 111
  - Normal/abnormal response 112
- Oxygen therapy 11, 13
- Oxygen uptake
  - Alveolar, measurement 1–2
  - Calculation 215–216
  - CWR tests 66
  - Effect of errors in r.p.m. (cadence) 240
  - External work rate coupling 1–2
  - Maximum*, cardiorespiratory fitness 230–233
  - Peak 210
  - Respiratory exchange ratio 2
  - R.p.m. error effects 22, 240
  - Systemic arterial pressure relationship 120
  - Time constant* 103–105
  - Calculation 104
  - CWR tests 65–66
  - Definition, derivation, and measurement units 103–104
  - Normal/abnormal response 104–105, 106
  - Treadmill and cycle exercise comparisons 24
  - See also breath-by-breath systems
- Oxygen uptake kinetics*, time constant, physical fitness assessment 8–9
- Oxygen analyzers 39–42
- Abnormal responses 99–100
- Cardiovascular disease classification 99–100
- Measured values 99
- Obesity complications 99–100
- Athletes 98
- Categories, AHA, Åstrand and Cooper tests 232–235, 238–239
- Definition, derivation, and measurement units 96–98, 209
- Estimation from predictive tests 211–215
- Incremental XT relationship 99
- Normal responses 98–99
- Physical fitness assessment 8–9
- Reference values 220–240
- Terminology 96–98
- Oxygenation, arterial, pulse oximetry 47–48
- Pacemaker, fixed-rate, XT relative contraindication 88
- Pallor, XT termination 88–89
- PaO₂ and PaCO₂ see arterial blood gas tensions

---

**Note:**

The above list is a compilation of terms and concepts covered in Exercise Testing and Interpretation: A Practical Approach by Christopher B. Cooper and Thomas W. Storer. The terms are organized alphabetically and include differential diagnoses, interventions, and measurement units relevant to exercise testing and interpretation. The page is an excerpt from a larger text, indicating the comprehensive nature of the subject matter covered in the book.
paramagnetic analyzers, oxygen analyzers 39
paresthesia, XT termination 89
pedal revolution counters see counters
performance exercise testing (PXT: fitness assessment) 6–9, 53–67
case study 185–191
defined 204
exercise prescription 53–54
field tests 55–60
fitness assessment 53
laboratory tests 60–67
maximal testing 66–67
progress monitoring 54–55, 54–55
purposes, setting and protocols 51, 52
submaximal testing 51, 52
pericarditis, XT contraindication 87
peripheral measuring devices 46–50
electrocardiography 46
pulse oximetry 47–50
sphygmomanometry 46–47
peripheral vascular disease 168
personnel
assignment 83–84
BP monitor 84
ECG technician 84
experience and qualifications 83
metabolic cart operator 85
supervision level 83
test administrator 84
pharmacological interventions 11, 13
pharmacotherapy, CXT progress monitoring 68
phosphate compounds, high-energy, production 2
phosphorylation coupling 2
physical activity readiness, protocol pro forma 252
physical deconditioning, cardiovascular response pattern abnormalities 165–166
physical training
assessment/preparation, case study 185–7
biomechanical efficiency 151
blood doping 168
cardiovascular limitation 163–164
data analysis, sequential graphing 162, 165
exercise prescription 11, 12
isowork analysis 151
oxygen pulse response patterns 112
response, PXT 8
response measurements 151
running economy 151
sinus bradycardia 113
physiological variables, glossary 205–210
“pink puffers”, lung disease 125
pitot tube, flow and volume transducers 37–38
pneumotachograph, flow and volume transducers 37
power, conversion constants 217
power output, cycle ergometers 22
Ppa see pulmonary arterial pressure
predicted normal values see reference values
prediction equations, reference values 150
pregnancy
XT guidelines 82–83
XT relative contraindication 88
premature atrial contractions (PACs), ECG 113
preoperative risk assessment, CXT 73
preparation for exercise program, case study 185–187
pressure, conversion constants 217
progress monitoring
CXT 68
PXT 54–55
propranolol, f\textsubscript{max} reduction 109
protein, respiratory quotient 7
protocol pro forma
cycle ergometers 254
physical activity readiness 252
preparation for exercise testing 251
preparticipation screening for exercise testing 253
treadmill ergometers 255
protocols and supplemental materials 241–260
psychological disorders
differential diagnosis 11
symptom perception abnormalities 178
XT contraindication 87
psychometric scales
Borg scale for perceived exertion 256
CXT 71
symptomatic evaluation, data analysis 155
P\textsubscript{a–et\textsubscript{CO\textsubscript{2}}} see arterial–end-tidal carbon dioxide partial pressure difference
P\textsubscript{o\textsubscript{2}} and P\textsubscript{CO\textsubscript{2}} see end-tidal gas tensions
pulmonary arterial pressure (P\textsubscript{pao}) 121–122
definition, derivation, equation, and measurement units 121, 207
normal/abnormal response 121–122
pulmonary capillary transit time (T\textsubscript{pc}), oxygen diffusion, alveolar–capillary membrane 138
pulmonary disease 11
arterial blood gas tension abnormalities 136
“blue bloaters”/“pink puffers” 125–126
breathlessness scores 147
cardiocirculatory response abnormalities 165–166
chronic, oxygen uptake, prolonged 105
dietary recommendations 126
differential diagnosis 11
exercise prescription 12
f\textsubscript{max} values 130
interstitial 11
oxygen breath decrease 131
P\textsubscript{pao} and P\textsubscript{co\textsubscript{2}} increases 140
progression/regression assessment 151–152
$P_{A-a}O_2$ widening 139
restrictive, ventilatory capacity reduction 124
symptom perception abnormalities 127–128, 177–178
$T/T_i$ 131, 133
vascular disease 11
ventilatory control abnormalities 173
ventilatory equivalents 135
ventilatory limitation 169
ventilatory response pattern abnormalities 170–171
$V_i$ values 128–129
see also chronic obstructive pulmonary disease; specific diseases
pulmonary embolism, XT contraindication 87
pulmonary rehabilitation initial assessment, case study 191–195
response 151
pulse oximetry arterial blood sampling 48–50
calibration, accuracy and precision 48
confounding factors 48
description and operational principles 47–48
maintenance 48
PWC170 test, electrically braked ergometers 23
PXT see performance exercise testing
Queen’s College single-stage step test 58–59, 214
questions, frequent 261–263
R see respiratory exchange ratio
ramp test 67
rating of perceived exertion (RPE) 144–146
Borg (psychometric) scale 144–146
definition, derivation, and measurement units 144–145, 207
$F_R$ relationship 145
interpretations 146
normal/abnormal response 145–146
recovery phase, data acquisition 86
reference values 220–240
reference values defined 149
prediction equations 150
single variable comparison 149–152
regression equation 16
rehabilitation CXT progress monitoring 68
response measurements 151
respiratory chain see mitochondrial pathway
respiratory compensation point 126–128
respiratory exchange ratio (R) 2, 105–107
calculation 216
carbon dioxide output and oxygen uptake relationship 2
measurement 105
definition, derivation, and measurement units 105–106, 207
normal/abnormal responses 106–107
time relationship 107
terminology 105–106
respiratory muscle weakness, ventilatory limitation 124, 169–171
respiratory quotient (RQ) defined 106
substrates 7
respiratory rate ($f_R$) 129–130
definition, derivation, and measurement units 129, 206
normal/abnormal response 129–130
resting phase, data acquisition 85
resuscitation equipment 90–91
crash cart 90–91
rheumatoid disorders, XT relative contraindication 88
risk assessment CXT 8, 68
preoperative 11, 13
Rockport walking test 55–56
estimation of maximum oxygen uptake 213–214
RPE see rating of perceived exertion
r.p.m. (cadence) conversion constants 217
effect of errors on mechanically braked, cycle ergometers 22–23
effect of errors on work rate and oxygen uptake 240
indicators see counters
RQ see respiratory quotient
RQmus see muscle respiratory quotient
running tests see walking and running tests
safety considerations 87–91
contraindications 87–90
JCAHO standards 87
Scholander procedure, calibration gas accuracy 40
shunt intracardiac, gas exchange abnormalities 175
physiological gas exchange abnormalities 173
$P_{A-a}O_2$ increase 139
shuttle test 10-meter 69–70
20-meter 57–58
course 19
speed definition, derivation, and measurement units 95–96
normal/abnormal responses 96
time intervals and estimated oxygen uptake 10-meter 69–70
20-meter 59
Siconolfi multistage step test 59–60, 212
sinus arrhythmias, ECG 113
sinus bradycardia 113
sinus tachycardia 113
Index

six-minute walking distance (dW6) see walking and running tests
skin symptoms, XT termination 88–89
slope, alveolar 137, 138, 140
slope of cardiovascular response
  definition, derivation, and measurement units 110–111, 205
  Fick equation 110
  normal/abnormal response 111
slope of ventilatory response
  definition, derivation, and measurement units 124, 205
  equation 124
  normal/abnormal response 125–126
smoking cessation 11, 13
solvents, occupational exposure, case study 195–199
speed, conversion constants 218
sphygmomanometry 46–47
  description and operational principles 46–47
  intraarterial blood pressure measurement 47
Korotkoff sounds, tonal quality and interpretation 119
spirometers and gasometers 35–36
  calibration, accuracy and precision 36
  description and operational principles 35–36
  dry gasometers 36
  dry rolling-seal 36
  maintenance 36
Ohio spirometer 36
Tissot spirometer 32
  leak tests 34
  water-sealed 35–36
sports medicine, ergometers 21
SpO2 see arterial oxygen saturation
stair-climb, chronic obstructive pulmonary disease 70
stair-step incremental work rate tests 67, 80–82
  Bruce and Balke treadmill protocols 64, 73, 78–79, 214–215
standard deviation of the mean
  confidence interval 150
  variability degree 140, 150
standardized gas volumes 215–216
  step tests 58–60
  oxygen cost 211–213
  Queen’s College single-stage step test 58–59, 214
  Siconolfi multistage step test 59–60, 214
  stair-step incremental work rate tests 67, 80–82
stoicism, symptom perception abnormalities 178
stopwatches see chronometers
Storer cycle test, estimation of maximum oxygen uptake 214
  suboptimal effort 156–7, 178–9
  supplemental materials 241–260
  surgery 11, 13
  CXT progress monitoring 68
SV see cardiac stroke volume
swim test 60, 236
symptom perception
  abnormalities 127–128, 177–178
  definition and identification 177
  data analysis 155
  rating of perceived exertion (RPE) 144–146, 207, 256
  systemic arterial pressure 206
t see endurance time
tachometer 20
  see also counters
tachycardia
  sinus, ECG 113
  supraventricular cardiovascular response pattern abnormalities 167
  ECG 113
  ventricular, ECG dysrhythmias 115
  XT termination 89
  TCA see Krebs cycle
testing methods see exercise testing (XT)
therapeutic interventions, evaluation 11, 13
thoracotomy, preoperative risk assessment, CXT 73
thromboembolic disease
  cardiovascular response pattern abnormalities 166
  XT contraindication 87
  see also pulmonary disease
thrombus, intracardiac, XT contraindication 87
thyrotoxicosis
  cardiovascular response pattern abnormalities 165
  XT relative contraindication 88
tidal volume (Vt) 128–129
  definition, derivation, and measurement units 128, 210
  equation 128
  normal/abnormal response 128–129
  Vt’ relationship 128, 129
  counters 20
  chronometers 19–21
  metronomes 20–21
  Tissot spirometer 32, 34
total lung capacity (TLC), inspiratory and expiratory
  flow–volume relationships 133–134
  Tpc see pulmonary capillary transit time
  transplantation, heart 11, 13
treadmill ergometers
  advantages and disadvantages 25
  calculation of grade increment 249
  calibration
    accuracy and precision 28–30
    pre-XT 78
  description and operational principles 27–28
  grading 28–29
  speed 29–30
  grading, angle relationship 29–30
  maintenance 30
maximal incremental work rate 80–82
oxygen cost
running 212
walking 211–212
walking and running tests 211–212
protocol pro forma 255
safety 30–31
settings 78
submaximal constant work rate 65
submaximal incremental work rate 63–64
Balke protocol 64, 214
Bruce protocol, data table 64, 214–215
tricarboxylic acid (TCA) cycle see Krebs cycle
TI/TE see inspiratory/expiratory time
turbine transducer, flow and volume transducers 38
vascular disease
peripheral, impaired oxygen delivery 168
pulmonary 11
ventilation
oscillating, ventilatory control abnormalities 173
treadmill and cycle exercise comparisons 24
see also hyperventilation; maximum minute ventilation;
maximum voluntary ventilation
ventilation disorders, differential diagnosis 10–11
ventilatory capacity
defined 208
determination pretest 76
spirometry 35
ventilatory capacity measurement, MVV 123
ventilatory control abnormalities
data analysis, nine-panel display 156–157, 172
definition and identification 171–172
diagnostic patterns 171–173
ventilatory equivalents* 134–135
definition, derivation, and measurement units 134, 208
equations 134
normal/abnormal response 134–135
ventilatory failure, ventilatory control abnormalities
172–173
ventilatory limitation 8, 10
data analysis 154, 159, 169–170
four-panel displays 160, 162
nine-panel display 156–157, 158, 169
definition and identification 124, 169
diagnostic patterns 169–170
ventilatory response pattern abnormalities
data analysis, nine-panel display 156–157, 170
diagnostic patterns 159, 170–171
ventilatory threshold
physical fitness assessment 9
respiratory compensation point* definition, derivation, and measurement units 126–127
normal/abnormal response 127–128
ventricular aneurysm, XT relative contraindication 88
ventricular contractions
ECG dysrhythmias 115
premature (PVCs), ECG 113
XT termination 89
ventricular fibrillation, ECG dysrhythmias 115
verapamil, fmax reduction 109
vent, XT termination 89
visual analog scale for breathlessness 146, 258
visual disturbance, XT termination 89
vital capacity (VC), nomograms 228–229
volume, conversion constants 218
volume transducers see flow and volume transducers
volume-measuring devices 32–43
desirable qualities 32
flow and volume transducers 36–35
gas collection bags 32–36
spirometers and gasometers 35–38
Vt see tidal volume
Vt/Ve see dead space–tidal volume ratio
walking and running tests
6- and 12-minute 69
6-minute walking test
definition, derivation, measurement units 94
equations 231
normal/abnormal responses 95
protocol 243
Cooper distance measurements 56–57, 237–239
1.5-mile run 237
3-mile walk 238
data analysis, sequential graphing 161–162
distance
definition, derivation, measurement units 94, 205
normal/abnormal responses 94
endurance time, normal/abnormal 93–94
oxygen cost, treadmill ergometers 211–212
Rockport 55–56
Shuttle 2-meter 57–58
timed 55–58
physical fitness assessment 9
see also treadmill ergometers
warm-up phase, data acquisition 85
water vapor pressure
gas analyzers 41
oxygen analyzers, calibration 41
water vapor pressure (Pw) 246
Weber classification, cardiovascular disease 99–100
weight, conversion constants 218–219
Wingate test, cycle ergometers 25
work, conversion constants 219
work efficiency* calculation 100
work efficiency (cont.)
definition, derivation, measurement units 100, 206
incremental exercise, oxygen uptake and work rate
relationship calculation 100
muscle work conversion 2
normal/abnormal response 100–101
physical fitness assessment 8–9
XT response variables 100–101
work rate increment 210
work rate and oxygen uptake, effect of errors in r.p.m. (cadence) 240
work rate tests
constant (CWR)
CXT 73–74
oxygen uptake time constant 65–66
\( t \), normal/abnormal responses 93, 94
\( f_{\text{max}} \) and \( f_r \)/work rate relationship 51, 52
incremental
arterial blood gas tensions 135, 136
cardiac output 117–118
\( f_r \) responses 129–130
maximal 66–67
maximum oxygen uptake relationship 99
minute ventilation and oxygen uptake relationship 123
\( P_{\text{a}-\text{o}} \) changes 139, 140
\( t \), normal/abnormal responses 93, 94
ventilatory equivalents 134–135
laboratory tests 66–67
oxygen uptake coupling 1–2
variable, \( t \), normal/abnormal responses 93–94
see also arm ergometers; cycle ergometers; treadmill ergometers; walking and running tests
work rate (W), defined 210

XT see exercise testing
YMCA cycle ergometer test 61
zirconium oxide analyzers, oxygen analyzers 39–40