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| **Author, Journal Title, Year** | **Purpose / Design** | **Subjects** | **Intervention/****Method** | **Outcome Measures** | **Pertinent Results** | **Application to PICO**  | **Comparison/ Notes** |
| Alberton et al., *European Journal of Applied Physiology*, 2011 | To examine and compare cardiorespiratory, neuromuscular, and kinematic responses to stationary running in water and stationary running on dry land. / Quasi-Experimental | 12 females, average age 22.3yo, experienced in water Aerobics | Stationary running (SR) on land versus SR in water, 4 minutes of each at submax speed and 15 s at max speed.  | Cadence, Maximum voluntary Contractions (MVC) and EKG of LE muscles, VO2, peak hip flexion and peak hip angular velocity.  | Cadence faster on land during max effort, VO2 & %VO2 peak higher on land, more gross LE muscle act. during submax on land but insig. diff at max levels. More hip angular V on land. | At max effort DWR has same effect on LE muscle activity.Cadence must be controlled to make DWR comparable to LR (max effort.)Less hip angular V in DWR due to water resistance.  | Less hip angular velocity in DWR = Less knee angular velocity, due to absent lag time (Kilding et al.) therefore, possibly longer delta T at knee and therefore less contact F at patellofem. J. |
| Peyre-Tartaruga et al, *Intl Journal of Aquatic Research and Edu.,* 2009 | To determine if an 8-wk running program with 30% deep water running (DWR) would allow competetive runners to sustain running kinematics, cardiorespiratory response, and land running (LR) performance./ RCT | 12 male and 6 female elite mid-distance runners, avg age 22.2 yo | Control group trained 6 sessions/ wk, of LR but experimental group did 30% of these sessions as DWR  | VO2 peak, 500m time, stride length, support time, nonsupport time, stride frequency, knee angle at heel strike, knee ankle at take off, 500 m time and horizontal V. RPE, end BMI.  | No sig. diff. between group’s 500 m times pre/post training. No sig. diff. in cardiopulm. Response. No sig. diff. in LR technique post program in exp. group or btwn groups. | Running performance maintained in 70%LR 30%DWR program. Integrated DWR into LR program does not alter LR kinematics even during fatigue. | Similar results found in Bushman et al. 4 week DWR program (although not elite runners.)/Study lacked explanation of DWR protocol. |
| Dierks et al, *Med. and Science in Sports and Exercise,* 2011 | To compare running kinematics during the stance phase between runners w/patellofemoral pain syndrome (PFPS) vs. runners without (PFPS) during states of physical exertion./ cohort study design | There were 20 recreation runners in either group; n=40. Age was between 18 and 45. Subjects were gender-matched (5 male 15 female)  | Subjects in either group ran on treadmill until exertion, pain or 85% of max HR was reached. Retrograde reflectors on landmarks were used for motion analysis.  | Kinematic measurement of joint angles including rear foot eversion, knee add. hip add., tibial IR, knee IR, hip IR, and knee flexion. Stance phase and tibial axial acceleration were also measured.  | Peak knee flex. & hip add. Were sig lower in PFPS group. Peak V was sig. less in PFPS group for hip add. & IR. Within the PFPS group, patterns of genu valgus, hip abd, or typical hip/knee add. Pattern. Eversion, knee IR, hip IR, and knee add. Angles were smaller for PFPS genu valgus & hip abd. groups.  | Decreased peak knee flexion and hip add. in runners with PFPS. General decreased motion and velocities n subjects with PFPS compared to controls. Both groups responded similarly to prolonged run (considering changes in relative kinematics.) | DWR activates adductors more so than LW or WW (Koichi et al.)Knee flexion similar in DWR and LR (Kidling et al.) but decreased delta T (Alberton et al.)/Kinematic differences cannot necessarily be attributed to pt.’s increased pain.  |
| Bushman et al., *Medicine and Science in Sports and Exercise*, 1997 | To investigate if a 4 week deep water running program could maintain running performance on land in trained competetive runners./ Longitudinal Cohort Study | 10 males and 1 female competitive recreational runners, average age 32.5 yo.  | Subjects completed 5-6 sessions per week for 4 weeks of DWR. Sessions were interval and endurance based. Intensity was matched with LR by RPE.  | Combined lactate threshold, max. oxygen consumption, running economy (amount of oxygen conumption required for the subject to run at a steady velocity) profile of mood states and a timed 5k on the treadmill. | Insig. diff. between pre and post test results for VO2 max, max HR, lactate threshold, running V, max lactate, 5k race time, scores on the profile of mood states and running economy.  | DWR has similar effect on mood as compared to LR. 4 weeks of solely DWR maintains physiological response and performance of runners.  | Compliance may be good for integrated DWR program. Similar results as Peyre-Tartaruga et al,/Sample only included men  |
| Heather Cichanowski et al. *Medicine and Science in Sports and Exercise,* 2007 | To determine if female collegiate athletes with PFPS had decreased hip strength in the effected LE as compared to the uneffected LE and as compared to matched controls./ quasi-experimental study design | 13 division 3 female athletes with PFPS and 13 age and sport matched controls without PFPS.  | Both groups completed isometric contractions of the 6 muscle groups of the hips on effected and unaffected LE’s. Measures were compared to control group.  | Isometric strength of the hip abductors, extensors, internal rotators, external rotators, flexors and extensors was measured.  | Sig. overall weakness of hip muscles in exp. group compared to controls. Sig. weaker hip abd. and ER in effected LE vs. unaffected LE of PFPS subjects.  | Females with PFPS should strengthen all 6 hip muscle groups, especially the ER’s and the abductors.  | Instability of aquatic environment= increased use of hip muscles as compared to walking on land (Koichi et al.) but less impact (Becker 2009) on patellof. Joint.More hip flex. In DWR (Kilding et al.) vs. LR. |
| Kilding et al*. J Strength and Cond Res,* 2007 | To investigate the kinematic motion of the lower extremities during deep water running versus running on land while maintaining similar stride frequencies. / Cross Sectional | 5 male distance runners without current illness or injury, with experience in DWR, and with an avg age 20.8 yo. | 5x 10m trials of LR & 5x 7m trials of DWR at either self-determined “slow” or “fast” pace. Stride frequency was controlled with metronome. Trials were recorded 2-deminsionally for analysis. | Peak angles of the hip and knee, ROM of the hip, knee and ankle during running, and lag time (between initiation of hip movement and initiation of knee movement.) | Overall more ROM at the hip and at the knee in DWR than in LR. DWR=more hip flexion but less hip extension than LR. DWR= More knee ext. than LR. No sig. diff. in knee flex. angles. No lag time in DWR between hip and knee (which is contrary to LR). | More ROM at the hip and knee. | More ROM may promote strength, may also promote increased ROM in PFPS pt.’s whom have limited ROM with LR.  |
| Escamilla, *Medicine and Science in Sports and Exercise*, 1998; vol. 30 No. 4 Pg. 556-569 | The purpose of this study was to investigate how dynamic open chain and closed chain exercises effect the cruciate ligament tensile forces, tibiofemoral compressive forces, patellofemoral compressive forces and muscle activity throughout a continuous and complete ROM of the knee.  | 10 males avg age 29yo w/o h/o knee pathology. With experience in both open and closed chain exercises.  | Each subject did 4 reps of squat, leg press, and leg extension. | Muscle activity of the three quadriceps muscles, medial and lateral hamstrings, and the gastroc. Resultant F’s and torques (external and inertial F’s only) were also measured, including tibiofemoral compressive F’s, PCL/ACL tensile F’s & patellofemoral compressive forces.  | Open chain quadriceps F greatest between 15 and 65 degrees, closed chain F greatest at angles above 83 deg. Lat HS activity greatest during closed chain. Patellofem. F’s increased with knee flexion & decreased with ext. In open chain, Patellof. F decreased when knee near full flex. Open chain = more patellofem. Compression during extension than closed chain. More F across joint when flexed above 83 degrees in closed chain.  | Patellofem. Pressure increased near flexion and decreased in ext.  | In open chain (which is DWR) patellofem. Compression decreased when near full flexion, therefore may allow more flexion in open chain without pain (when considering knee angle during stance phase or LR)  |
|  Koichi, *Journal of Electromyography and Kinesiology*, 2008  | To use EMG data from the hip and trunk muscles during DWR in order to compare the muscle activity to that of walking in water (WW) and walking on land (LW).  | 9 males with an average age of 25.1 years. The average height, weight, and BMI were also recorded for each subject. The subjects were not described at athletes.  | Each subject. completed MVC for specified muscles of the left LE, completed LW, WW and DWR trials at a self-determined pace with 2 reps of 8 sec at 2 diff. self-determined paces of slow, moderate, and fast. EMG activity was recorded during each trial | EMG of adductor longus, glut. max, glut med, rectus abdominus, external oblique, and erector spinae. Video recordings taken from left sagitall view. Kinematic variables included locomotion speed, time of a single cycle, ROM of the hip joint, and the angle of the trunk and pelvis in relation to vertical. | cycle locomotion speed: LW had the shortest cycle, followed by DWR and lastly WW. Higher MVC was noted for the add. longus, glut. Med., rectus abdominus, ext. oblique, erector spinae and glut max. in DWR as compared to LW and WW. Hip joint ROM: DWR = higher than either LW or WW. DWR = more forward inclination of the trunk compared to LW and WW.  | More muscle activation in DWR than LR or WW. Cycle locomotion speed faster in LW than DWR. | DWR more optimal for return to sport compared to land walking (or water walking.)Cadence control in DWR vital to success. |
| Becker, *Physical Med and Rehab.,* 2009 | To describe the various physiologic changes that can occur in the aquatic environment, and how these changes can be tailored for benefit in aquatic exercise programs for diverse patient populations. /Systemic Review | This article included information about how various population can benefit from aquatic therapy, including cardiovascularcardiopulm., athletic rehab, geriatrics, pregnant pts, pts w/OA, psychiatric pts, and obesity rehab.  | Various Methods of Aquatic Therapy | Physical principles of water including density, hydrostatic pressure, buoyancy, viscosity, thermodynamics. Application of aquatic therapy to various described patient populations. | The aquatic therapy environment is vastly under-used. The authors also conclude that the water immersion can offer incredibly beneficial effects to diverse patient populations, and that aquatic exercise is just as beneficial if not more beneficial than other more common sources of exercise.  | Understanding of the properties of water and how water immersion may effect the body.  | Buoyancy= decreased weight bearing. Increased velocity = increased resistance (therefore DWR at max effort with controlled cadence = comparable to LR in terms of physiologic response). |