노인의 넘어짐으로 인한 고관절 골절 예방프로그램의 효과: 문헌 고찰

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The Literature Review on the Effectiveness of Fall-related Hip Fracture Prevention Programs

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Key Words

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While efforts have been made to address fall-related injuries in older adults, the problem is unsolved to date. The purpose of this review is to provide a guideline for fall and injury prevention programs in older adults, based on evidence generated over the past 30 years. Research articles published between 1990 and 2020 have been searched on PubMed, using keywords, including but not limited to, falls, hip fracture, injuries, intervention, older adults, prevention, hip protector, vitamin D, safe landing strategy, and exercise. Total of 98 articles have been found and categorized into five intervention areas: exercise program, hip protector, safe landing strategy, vitamin D intake, and compliant flooring. Furthermore, the articles have been rated based on their study design: class 1, randomized controlled trials; class 2, non-randomized controlled trials; class 3, experimental studies; class 4, all other studies. Exercise programs have shown to decrease the risk of fall, and associated injuries. Hip protectors, safe landing strategy, and vitamin D intake were effective in reducing a risk and incidence of hip fracture during a fall. Furthermore, compliant flooring has also decreased hip fracture risk without affecting balance. An integrated approach combining exercise program, wearing a hip protector, teaching safe landing strategies, scheduled vitamin D intake, and compliant flooring installation, is suggested to address fall-related injuries in older adults.

INTRODUCTION

노인 낙상을 줄이기 위해 많은 노력이 있었음에도 불구하고 지난 10여년간 노인의 넘어짐으로 인한 사망률은 지속적으로 증가했고, 2030년까지 시간당 7명의 사망률을 예측하고 있다[1]. 연구결과를 바탕으로 여러 중재법이 제시되어 오고 있음에도 불구하고, 노인 낙상 문제가 쉽게 해결되지 않는 이유는 증가하는 노인 인구에 있기도 하지만, 왜 넘어지고, 어떤 넘어짐이 골절을 유발하는지에 대한 불명확한 이해가 이유이기도 하다. 실제로 1%~2%의 노인의 넘어짐만이, 생명을 위협하는 고관절 골절을 일으키는데[2], 왜 그런지에 대한 명확한 이해는 부족한 실정이다. 다행히도 연구자들의 노력으로 골절 위험도에 영향을 미치는 10여 가지의 생체역학적 요인들이 확인되었고, 이를 바탕으로 중재법들이 제안되어 오고 있지만, 완전한 이해를 위해서는 지속적인 연구가 필요한 실정이다.

본 리뷰의 목적은, 현재까지 제시된 증거 기반 노인 넘어짐 및 고관절 골절 예방프로그램의 효과를 고찰하고, 노인 낙상예방을 위한 통합적인 중재법의 방향성을 제시함에 있다. 이를 위해, 현재까지 알려진 노인 낙상 예방 중재 방법을 운동프로그램(i.e., 균형능력증진, 근력강화, 지구력강화 등), 고관절 보호대의 사용, 안전하게 넘어지는 전략(i.e., 구르기, 엉덩이와 무릎이 동시에 바닥에 닿기 등), 비타민 D 섭취, 그리고 충격 흡수 매트 등 5가지 영역으로 나누고, 각 영역별로 현재까지 출판된 논문을 정리하여 고찰하였다.

MATERIALS AND METHODS

1. 논문 검색 및 분류 방법

1990년부터 2020년까지 출판된 논문들이 PubMed를 통해 검색되었다. 사용된 키워드로는 Falls, hip fracture, injuries, intervention,

older adults, prevention, hip protector, vitamin D, safe landing strategy, exercise 등을 포함했다. 검색 결과, 308개의 영어 논문이 검색되었으나, 종설 논문과 초록 및 원문 확인이 불가능한 원저 논문, 그리고 Journal Citation Report에 색인되어 있지 않은 논문을 제외하여 총 117편의 논문이 확인되었다. *Physical Therapy Korea* 종설 논문 참고문헌 개수 제한에 따라 journal impact factor percentile 하위 19개의 논문을 제외하고, 총 98편의 논문이 운동프로그램(44편), 고관절 보호대(28편), 안전하게 넘어지는 전략(13편), 비타민 D 섭취(9편), 그리고 충격 흡수 매트(6편) 등 5가지 영역으로 나누어 고찰되었다(Table 1). 또한, 연구 논문 결과의 영향력을 구분하기 위해, 연구 디자인에 따라 다음의 네 개의 등급으로 나누어 고찰하였다. 1등급, 무작위 대조실험연구(randomized controlled trials); 2등급, 대조실험연구(non-randomized controlled trials); 3등급, 대조군 없는 실험 연구(experimental studies); 4등급, 1, 2, 3등급에 속하지 않은 모든 유형의 연구(i.e., case study 등).

RESULTS

1. 운동프로그램

노인의 균형 능력 증진을 통한 낙상예방을 위한 운동중재는 다양한

Table 1. The number of articles included in this review

Interventions	Class of evidence ^a				Total
	1	2	3	4	
Exercise programs	33	2	8	1	44
Hip protector	14	5	9	0	28
Safe landing strategy	0	4	9	0	13
Vitamin D intake	8	1	0	0	9
Compliant flooring	1	2	3	0	6

^aClass 1: randomized controlled trials. Class 2: non-randomized controlled trials. Class 3: experimental studies with no control group. Class 4: studies not belonging to Class 1, 2, and 3 (i.e., case study).

Table 2. Effect of exercise on static balance

Articles	Class of evidence	Interventions	Outcomes	Improve
Kurz et al., 2016 [3]	1	Unexpected perturbation training	COP	Yes
Alfieri et al., 2012 [4]	1	Multisensory training	COP	Yes
Hatzitaki et al., 2009 [5]	1	Visually guided weight-shifting	COP	Yes
Li et al., 2004 [6]	1	Tai Chi	FRT	Yes
Cyarto et al., 2008 [7]	1	Group exercise	OLS	Yes
Szturm et al., 2011 [8]	1	Interactive computer game	Loss of balance	Yes
Barnett et al., 2003 [9]	1	Group exercise	COP	Yes
Jorgensen et al., 2013 [10]	1	Nintendo Wii	COP	No
Martínez-Amat et al., 2013 [11]	2	Bosu and Swiss ball	COP	Yes
Bulat et al., 2007 [12]	3	Group exercise	1. COP 2. CTSIB	1. Yes 2. Yes
Springer et al., 2018 [13]	3	Thoracopelvic assisted movement	FRT	Yes
Sung et al., 2018 [14]	4	Tai Chi	FRT	Yes

COP, center of pressure; FRT, functional reach test; OLS, one leg standing test; CTSIB, clinical test of sensory integration on balance.

연구에서 검증되었으며, 연구들의 결과 변수에 따라 정적 균형, 동적 균형, 통합 균형(정적 균형과 통합 균형을 함께 확인하는 결과변수), 설문지, 넘어짐 또는 골절 횟수로 나누어 고찰되었다.

1) 정적 균형

압력 중심점의 궤도(trajecory of center of pressure)를 통해 균형 증진이 확인된 운동은 갑작스러운 속도 변화 훈련(unexpected perturbations training), 다감각 훈련(multisensory training), 시각 유도 무게 이동(visually guided weight-shifting), 보수와 스위스볼(Bosu and Swiss ball), 그룹 운동(group exercise) 등이 있었다(Table 2) [3-14]. 기능적 팔 뻗기 검사를 통해 균형 능력 증진이 확인된 운동은 태극권(Tai Chi), 흉부골반 보조 운동(thoracopelvic assisted movement) 등이 있었다. 한발 서기 검사를 통해 균형 증진을 확인한 운동은 그룹 운동(group exercise)이 있었다. 그 외 컴퓨터 게임을 적용하여 균형을 잃은 횟수를 통해 균형 능력 증진을 확인하였으며, 그룹 운동을 적용하여 균형감각조절임상검사를 통해 균형 능력 증진을 확인하였다.

2) 동적 균형

보행 속도 확인을 통해 균형 증진을 확인한 운동중재에는 노르딕 보행(Nordic walking), 흔들의자 가정기반운동(home-based rocking chair exercise), 강렬한 운동(intensive exercise), 시각 보조 트레드밀(projected visual context treadmill), 장기간 강화 및 균형 훈련(long-term strength and balance training), 넘어짐 예방 프로그램(fall prevention program), 흉부골반 보조 운동(thoracopelvic assisted movement), 태극권(Tai Chi), 이중 작업 훈련(dual-task training)이 있었다(Table 3) [15-23]. 보행 변수들을 통해 균형 증진을 확인한 운동은 이중 작업 훈련(dual-task training)이 있었다. 동적 보행 지수를 통해 균형 증진을 확인한 운동은 이중 작업 훈련(dual-task training), 태극권(Tai Chi), 물리치료중재(physical therapeutic intervention)가 있었다. 보행 중 총 이동거리를 통해 균형 증진을 확

Table 3. Effect of exercise on dynamic balance

Articles	Class of evidence	Interventions	Outcomes	Improve
Gomeñuka et al., 2019 [15]	1	Nordic walking	Gait speed	Yes
Niemelä et al., 2011 [16]	1	Home-based rocking-chair exercise	Gait speed	Yes
Oh et al., 2012 [17]	1	Intensive exercise	Gait speed	Yes
van Ooijen et al., 2016 [18]	1	Projected visual context treadmill	Gait speed	Yes
Li et al., 2004 [6]	1	Tai Chi	Dynamic gait index	Yes
Wolf et al., 2001 [19]	1	Physical therapeutic intervention	Dynamic Gait Index	Yes
Conradsson and Halvarsson, 2019 [20]	1	Dual-task balance training	Gait parameters	Yes
Barnett et al., 2003 [9]	1	Group exercise	Gait speed	No
Springer et al., 2018 [13]	3	Thoracopelvic assisted movement	Gait speed	Yes
Li, 2014 [21]	3	Tai Chi	Gait speed	Yes
Dorfman et al., 2014 [22]	3	Dual-task training	1. Gait speed 2. Dynamic gait index	1. Yes 2. Yes
Renfro et al., 2016 [23]	3	Modified Otago exercise program	Total walk distance	Yes

Table 4. Effect of exercise on balance (studies using clinical balance measurement tools)

Articles	Class of evidence	Interventions	Outcomes	Improve
Binder et al., 2002 [24]	1	Intensive exercise training	Performance test	Yes
Cyarto et al., 2008 [7]	1	Group-based resistance and balance training	8-foot up-and-go test	Yes
Frih et al., 2018 [25]	1	Combined exercise	1. TUG 2. Tinetti 3. BBS	1. Yes 2. Yes 3. Yes
Irlandoust et al., 2019 [26]	1	Aquatic exercise	Tinetti	Yes
Jorgensen et al., 2013 [10]	1	Nintendo Wii	1. TUG 2. Chair stand test	1. Yes 2. Yes
Lai et al., 2013 [27]	1	Video game with exercise	1. BBS 2. TUG	1. Yes 2. Yes
Leiros-Rodríguez and García-Soidan, 2014 [28]	1	Balance training	1. BBS 2. TUG	1. Yes 2. Yes
Li et al., 2004 [6]	1	Tai Chi	BBS	Yes
Li et al., 2018 [29]	1	Biofeedback balance training with functional electrical stimulation	BBS	Yes
Mihailov and Popa, 2010 [30]	1	Long term exercise	1. Tinetti 2. TUG	1. Yes 2. Yes
Niemelä et al., 2011 [16]	1	Home-based rocking-chair exercise	BBS	Yes
Pollock et al., 2012 [31]	1	Whole body vibration with strength and balance exercise	TUG	Yes
Pooranawatthanakul and Foongchomcheay, 2015 [32]	1	Video game (Wii)-based exercise	1. BBS 2. Fullerton	1. Yes 2. Yes
Steadman et al., 2003 [33]	1	Enhanced balance training	BBS	Yes
Wolf et al., 2001 [19]	1	Balance training	BBS	Yes
Zhang et al., 2014 [34]	1	Whole body vibration	TUG	Yes
Szturm et al., 2011 [8]	1	Interactive computer game exercise	1. BBS 2. TUG	1. Yes 2. No
Hale et al., 2012 [35]	1	Water based exercise	TUG	No
Sherrington et al., 2020 [36]	1	Recovery exercise after fracture	SPPB	No
Martínez-Amat et al., 2013 [11]	2	Proprioception training	1. BBS 2. Tinetti	1. Yes 2. Yes
Bulat et al., 2007 [12]	3	Functional balance training	BBS	Yes
Dorfman et al., 2014 [22]	3	Dual tasking on treadmill	BBS	Yes
Li, 2014 [21]	3	Tai Chi	TUG	Yes
Springer et al., 2018 [13]	3	Thoracopelvic assisted movement training	TUG	Yes

인한 운동은 수정된 오타고 운동 프로그램(modified Otago exercise program)이 있었다.

3) 통합 균형

정적 및 동적 균형을 함께 측정할 수 있는 임상균형측정 도구는 버그 균형척도(Berg Balance scale, BBS), 일어서서 걷기검사(Timed Up

and Go, TUG), 실행지향움직임 평가(Tinetti Performance Oriented Mobility Assessment, POMA), 플러턴 어드밴스드 균형척도(Fullerton Advanced Balance Scale), 의자에서 일어나기(Chair stand test), 8-foot up-and-go test, 수정된 운동수행검사(Physical Performance Test), 간편신체기능검사(Short Physical Performance Battery, SPPB) 등 다양했는데, 이러한 임상균형측정 도구를 이용해 균형 능력 증진을 확인한 운동은 더욱더 다양했다(Table 4) [24-36].

4) 설문지

넘어짐 효능감 척도(fall efficacy scale)를 통해 균형 증진을 확인한 운동은 닌텐도 위(Nintendo Wii), 태극권(Tai Chi), 상호작용 비디오 게임(interactive video game), 기능적 전기 자극을 통한 시각 피드백 기반 훈련(visual feedback based training with functional electric stimulation), 가정기반 운동 프로그램(home-based exercise program), 전신 진동(whole body vibration)이 있었다(Table 5)

[37-43]. 행동특이적 균형 자신감 척도(activities-specific Balance Confidence Scale)를 통해 균형 증진을 확인한 운동은 지구력 저항 운동(endurance-resistance exercise), 니즈메겐 넘어짐 예방 프로그램(Nijmegen fall prevention program), 상호작용 컴퓨터 게임(interactive computer game), 전신 진동(whole body vibration)이 있었다. 두려움 척도(fear of falling)를 통해 균형 증진을 확인한 운동은 시각 보조 트레드밀(projected visual context treadmill), 기능적 순환 훈련(functional circuit training), 시각적 피드백 균형 훈련(visual feedback based balance training), 태극권(Tai Chi)이 있었다.

5) 넘어짐 및 골절 횟수

넘어짐 횟수(number of falls) 및 골절 횟수(fracture incidence)를 통해 낙상예방 효과를 확인한 운동은 가정 기반 운동(home based exercise), 가상 현실을 이용한 균형 운동(balance exercise with using virtual reality), 기능적 전기 자극을 함께 사용한 시각 피드백 기반 힘판 훈련(visual feedback-based force platform training with

Table 5. Effect of exercise on balance (studies using questionnaires)

Articles	Class of evidence	Interventions	Outcomes	Improve
Frih et al., 2018 [25]	1	Endurance-resistance exercise	ABC	Yes
Smulders et al., 2010 [37]	1	Nijmegen fall prevention program	ABC	Yes
Szturm et al., 2011 [8]	1	Interactive computer game	ABC	Yes
Zhang et al., 2014 [34]	1	Whole body vibration	ABC	Yes
Jorgensen et al., 2013 [10]	1	Nintendo Wii	FES	Yes
Lai et al., 2013 [27]	1	Interactive video game	FES	Yes
Li et al., 2018 [29]	1	Visual feedback-based training with functional electric stimulation	FES	Yes
Pollock et al., 2012 [31]	1	Whole body vibration	FES	Yes
van Ooijen et al., 2016 [18]	1	Projected visual context treadmill	Fear of falling	Yes
Giné-Garriga et al., 2013 [38]	1	Functional circuit training	Fear of falling	Yes
Sihvonen et al., 2004 [39]	1	Visual feedback-based balance training	Fear of falling	Yes
Wolf et al., 1996 [40]	1	Tai Chi	Fear of falling	Yes
Zeeuwe et al., 2006 [41]	1	Tai Chi	Fear of falling	Yes
Cyarto et al., 2008 [7]	1	Group exercise	ABC	No
Hale et al., 2012 [35]	1	Water-based exercise	ABC	No
Kurz et al., 2016 [3]	1	Unexpected perturbations training	FES	No
Barnett et al., 2003 [9]	1	Group exercise	Fear of falling	No
Wolf et al., 2001 [19]	1	Physical therapeutic intervention	Fear of falling	No
Miller et al., 2010 [42]	3	Home-based exercise program	FES	Yes
Groen et al., 2010 [43]	3	Martial arts	Fear of falling	Yes

ABC, activities-specific balance confidence scale; FES, fall efficacy scale.

Table 6. Effect of exercise on fall and fracture incidence

Articles	Class of evidence	Interventions	Outcomes	Improve
Campbell et al., 1997 [44]	1	Home based exercise	Fall incidence	Yes
Duque et al., 2013 [45]	1	Balance exercise using Virtual Reality	Fall incidence	Yes
Li et al., 2018 [29]	1	Visual feedback-based force platform training with functional electrical stimulation	1. Fall incidence 2. Fracture incidence	1. Yes 2. Yes
Sihvonen et al., 2004 [39]	1	Biofeedback balance training	Fall incidence	Yes
Swanenburg et al., 2007 [46]	1	Exercise with calcium and vitamin supplement	Fall incidence	Yes
van Ooijen et al., 2016 [18]	1	Treadmill training with projected visual context	Fall incidence	No
Sherrington et al., 2020 [36]	1	RESTORE intervention	Fall incidence	No

functional electrical stimulation), 칼슘-비타민 보충제 복용과 함께한 운동(exercise with calcium and vitamin supplement), 시각 보조 트레드밀 (treadmill training with projected visual context), RESTORE 치료(RESTORE intervention) 등이 있었다(Table 6) [44-46].

2. 고관절 보호대

노인의 넘어질 때 발생하는 고관절 골절예방을 위한 고관절 보호대 효과를 검증한 연구에서 사용된 결과 변수로는 골절 발생률(hip fracture incidence), 넘어짐 및 부상에 대한 두려움(fear of fall and injury risk), 충격힘 등이 있었다. 넘어지는 상황에서 고관절 보호대가 잘 착용되어 있으면, 대퇴골에 가해지는 충격힘을 상당히 줄여서, 골절 발생률을 줄일 수 있었을 뿐 아니라, 넘어짐 및 부상에 대한 두려움도 상당히 감소됨을 확인할 수 있었다(Table 7) [47-74].

3. 안전하게 넘어지는 전략

넘어지는 방법에 따라 엉덩이가 바닥에 닿을 때 대퇴골에 가해지는 충격힘을 줄여 고관절 골절 위험도를 크게 낮출 수 있었는데, 안전한 넘어짐 전략은 넘어질 때 고관절 근 수축(hip muscle contraction),

무술(martial arts), 충격 시 몸통 및 무릎의 위치(trunk and knee position), 골반 충격 각도(pelvis impact angle), 팔 위치(arm configuration) 등이 있었다(Table 8) [75-86]. 특히 무술(martial arts), 목 근육 활성화(neck muscle activation) 등은 충격 속도를 줄여 골절 위험을 크게 낮추었다. 대퇴경부에 발생하는 스트레스 또는 축방향 힘을 줄인 전략은 고관절 벌림근력(hip abductor muscle forces), 충격 시 무릎의 위치(knee boundary conditions), 골반 충격 각도(pelvis impact angle)이 있었다.

4. 비타민 D 섭취

비타민 D 섭취가 낙상 예방에 미치는 효과를 검증한 연구들은 넘어짐 및 부상률(fall and injury rate), 넘어짐 위험률(fall risk), 균형 능력(balance), 자세불안정성(posture instability) 등의 결과 변수를 사용하였다. 비타민 D 섭취는 노인의 넘어짐 및 부상률뿐만 아니라 균형능력이 증진되어 넘어짐 위험률을 효과적으로 감소시켰다(Table 9) [87-94].

5. 충격 흡수 매트

노인 낙상 위험도는 바닥재에 따라 큰 영향을 받았는데, 고무 재질의

Table 7. Effect of a hip protector on fall-related hip fracture risk

Articles	Class of evidence	Interventions	Outcomes	Improve
Bentzen et al., 2008 [47]	1	Hip protector	Hip fracture incidence	Yes
Cameron et al., 2000 [48]	1	Hip protector	Fear of fall and injury risk	Yes
Kannus et al., 2000 [49]	1	Hip protector	Hip fracture incidence	Yes
Koike et al., 2009 [50]	1	Hip protector	Hip fracture incidence	Yes
Lauritzen et al., 1993 [51]	1	Hip protector	Hip fracture incidence	Yes
Meyer et al., 2003 [52]	1	Hip protector	Hip fracture incidence	Yes
Cameron et al., 2011 [53]	1	Hip protector	1. Fear of fall and injury risk 2. Hip fracture incidence	1. No 2. No
Cameron et al., 2011 [54]	1	Hip protector	Fear of fall and injury risk	No
Cameron et al., 2003 [55]	1	Hip protector	1. Fear of fall and injury risk 2. Hip fracture incidence	1. No 2. No
Birks et al., 2004 [56]	1	Hip protector	Hip fracture incidence	No
Kiel et al., 2007 [57]	1	Hip protector	Hip fracture incidence	No
O'Halloran et al., 2004 [58]	1	Hip protector	Hip fracture incidence	No
van Schoor et al., 2003 [59]	1	Hip protector	Hip fracture incidence	No
Birks et al., 2003 [60]	1	Hip protector	Hip fracture incidence	No
Harada et al., 2001 [61]	2	Hip protector	Hip fracture incidence	Yes
Garfinkel et al., 2008 [62]	2	Hip protector	Hip fracture incidence	Yes
Juby, 2009 [63]	2	Hip protector	Hip fracture incidence	Yes
Korall et al., 2019 [64]	2	Hip protector	Hip fracture incidence	Yes
Woo et al., 2003 [65]	2	Hip protector	Hip fracture incidence	Yes
Bentzen et al., 2008 [66]	3	Hip protector	Hip fracture incidence	Yes
Forsén et al., 2003 [67]	3	Hip protector	Hip fracture incidence	Yes
Honkanen et al., 2005 [68]	3	Hip protector	Hip fracture incidence	Yes
O'Halloran et al., 2007 [69]	3	Hip protector	Hip fracture incidence	No
Laing et al., 2011 [70]	3	Hip protector	Hip impact force	Yes
Laing and Robinovitch, 2008 [71]	3	Hip protector	Hip impact force	Yes
Laing and Robinovitch, 2008 [72]	3	Hip protector	Hip impact force	Yes
Choi et al., 2010 [73]	3	Hip protector	Hip impact force	Yes
Choi et al., 2010 [74]	3	Hip protector	Hip impact force	Yes

Table 8. Effect of safe landing strategies on fall-related hip fracture risk

Articles	Class of evidence	Interventions	Outcomes	Improve
Martel et al., 2018 [75]	2	Hip muscle contraction	Hip impact force	Yes
Pretty et al., 2017 [76]	2	Hip muscle contraction	Hip impact force	Yes
Groen et al., 2007 [77]	2	Martial arts	1. Hip impact force 2. Hip impact velocity	1. Yes 2. Yes
Weerdesteyn et al., 2008 [78]	2	Martial arts	1. Hip impact force 2. Hip impact velocity	1. Yes 2. Yes
Robinovitch et al., 1997 [79]	3	Trunk position	Hip impact force	Yes
van der Zijden et al., 2012 [80]	3	Martial arts	Hip impact force	Yes
Lim and Choi, 2020 [81]	3	Knee boundary condition	Hip impact force	Yes
Choi et al., 2010 [73]	3	Pelvis impact angle	Hip impact force	Yes
DeGoede and Ashton-Miller, 2002 [82]	3	Arm configuration	Hip impact force	Yes
Choi et al., 2017 [83]	3	Neck muscle activation	Hip impact velocity	Yes
Lo and Ashton-Miller, 2008 [84]	3	Segment movement	Hip impact force	Yes
Choi et al., 2015 [85]	3	Hip abductor muscle forces, Knee boundary conditions	1. Femoral neck stress 2. Femoral neck force	1. Yes 2. Yes
Choi and Robinovitch, 2018 [86]	3	Pelvis impact angle	1. Femoral neck stress 2. Femoral neck force	1. Yes 2. Yes

Table 9. Effect of vitamin D intake on fall-related hip fracture risk

Articles	Class of evidence	Interventions	Outcomes	Improve
Uusi-Rasi et al., 2015 [87]	1	Vitamin D (800 IU)	Fall and injury rate	Yes
Bischoff-Ferrari et al., 2016 [88]	1	Vitamin D	Fall and injury rate	Yes
Smith et al., 2017 [89]	1	Vitamin D (4,000–4,800 IU)	Fall and injury rate	Yes
Bogaerts et al., 2011 [90]	1	Vitamin D with squat	1. Fall and injury rate 2. Balance	1. Yes 2. Yes
Swanenburg et al., 2007 [46]	1	Vitamin D with protein, balance exercise	1. Fall risk 2. Balance	1. Yes 2. Yes
Bischoff-Ferrari et al., 2006 [91]	1	Vitamin D and calcium	Fall risk	Yes
Law et al., 2006 [92]	1	Vitamin D	Fall and injury rate	No
Sanders et al., 2010 [93]	1	Vitamin D	Fall and injury rate	No
Boersma et al., 2012 [94]	2	Vitamin D	Postural instability	Yes

Table 10. Effect of compliant flooring on fall-related hip fracture risk

Articles	Class of evidence	Interventions	Outcomes	Improve
Mackey et al., 2019 [95]	1	Compliant (low-stiffness) flooring	Fall and injury risk	No
Simpson et al., 2004 [96]	2	Wooden carpeted floors	Fall and injury	Yes
Laing and Robinovitch, 2009 [97]	2	Smart Cell (low- stiffness)	Hip impact	Yes
Gustavsson et al., 2018 [98]	3	Compliant (low-stiffness) flooring	Fall and injury risk	Yes
Wright and Laing, 2011 [99]	3	Smart Cell and Softile	Femur peak force	Yes
Gustavsson et al., 2015 [100]	3	Impact absorbing flooring	Fall and injury risk	Yes

충격 흡수 매트는 균형에 나쁜 영향을 미치지 않으면서, 넘어질 때 발생하는 충격힘을 줄임으로써, 넘어짐 및 골절 위험도를 크게 낮추었다 (Table 10) [95–100].

DISCUSSION

1. 운동프로그램

태극권, 전신 진동을 이용한 운동 그리고 닌텐도 위를 활용한 운동프로그램은 다른 운동들과 비교하였을 때, 많은 수의 논문들이 출판되었으며 대부분 무작위 대조군 실험을 통해 정적, 동적, 그리고 통합 균형

및 넘어짐 효능감과 두려움에 대해 효과가 있음을 밝혔으므로, 본 문헌 고찰에서는 해당 운동들을 권장한다.

그 외에, 낙상 횟수의 감소에 영향이 있었던 7개의 운동들은 대부분 무작위 대조군 실험을 통해 효과를 증명하였다. 하지만, 7개의 연구 중, 고관절 골절 횟수를 결과 변수로 포함시킨 연구는 1개에 불과했다. 골절예방을 위한 운동프로그램의 확실한 효과를 확인하기 위해 더 많은 연구가 필요해 보인다.

2. 고관절 보호대

임상 연구 결과에 따라 고관절 보호대의 고관절 골절 예방 효과에 대

해 긍정적으로 보기도 하고 부정적으로 보기도 했다. 그러나 생체역학 연구에서는 넘어질 때 올바르게 착용된 고관절 보호대는 충격힘을 최대 50%까지 줄일 수 있어 고관절 골절 예방에 큰 도움이 된다고 보고한다. 이는, 고관절 보호대의 처방뿐 아니라, 실제로 잘 착용하고 있는지에 대한 확인 및 교육이 중요함을 말해 준다. 따라서, 노인 본인뿐 아니라 관련 보건의로 인력들은 고관절 보호대의 적절한 사용을 교육 및 모니터링 할 필요가 있다.

3. 안전하게 넘어지는 전략

안전한 넘어짐 전략은 넘어짐으로 인한 심각한 손상을 예방하기 위하여 중요하다. 본 문헌 고찰에서 제시된 연구들로 제안된 전략들은 대부분 넘어지는 동안 고관절과 머리에 가해지는 충격에 대하여 초점이 맞춰져 있었다. 안전한 전략의 정도를 논하기 위해서 연구들에서는 보통 충격힘(impact force)과 충격 속도(impact velocity) 그리고 뼈에 가해지는 스트레스와 축 방향 힘(stresses and axial forces)을 결과변수로 사용하였으며, 제시된 전략은 무술 동작을 하는 것(martial arts), 다른 방향으로 골반에 충격이 가도록 넘어지는 것(pelvis impact angle), 신체 분절의 위치를 바꿔 넘어지는 것(segment movement), 넘어지는 동안 근육 수축을 하는 것(muscle activation during a fall)이 있었으며, 제시된 방법 모두 효과가 있다고 보고되었다. 그러나, 본 연구에서는 넘어지는 동안 노인에게 미칠 영향을 알고자 하였으나, 대부분의 연구가 젊은 대상자에게 넘어짐 전략을 적용하거나, 고관절 충격 시뮬레이터를 이용하여 노인의 뼈에 가해질 충격을 예측하였다. 노인에게 직접적으로 실험을 진행할 수 없었던 것은 실험 간 발생할 가능성이 있는 문제(예를 들면, 골절 및 타박상)를 마주하지 않기 위해서였으나, Groen 등[43]은 실제 노인을 대상으로 무술 훈련이 충격힘을 8%까지 줄일 수 있다는 것을 보고하였다.

4. 비타민 D 섭취

노쇠한 노인(비타민 D의 결핍이 있는 노인)의 넘어짐과 부상을 예방하기 위해 비타민 D의 섭취가 권장됐고, 고용량 비타민 D (800 IU) 이상의 섭취는 넘어짐 및 부상으로부터 본인을 보호할 수 있었다. 낙상 예방프로그램에 규칙적인 비타민 D 섭취 포함, 혹은 국가 복지 사업으로 고위험군 노인에게 비타민 D 보급 등을 통한 적극적인 대응은 노인 낙상 문제를 해결하는 데 도움이 될 것이다. 뿐만 아니라, 비타민 D 섭취와 병행하여 칼슘 섭취 및 운동을 실행하면 낙상 예방에 더 효과적인 것으로 보인다.

5. 충격 흡수 매트

충격 흡수 매트는 노인의 넘어짐 및 부상 위험률을 증가시키지 않는다고 하였다. 이는 일부 낮은 강성의 표면이 균형 유지 및 균형 회복 능력을 손상시켜 낙상 위험을 증가시킬 수 있다는 우려를 불식시키는 연구 결과이다[97]. 오히려, 넘어질 때 발생하는 충격힘을 최대 50%까지 줄여, 골절 위험률을 줄이게 된다. 충격 흡수 매트는 균형과 안정성에

영향을 미치지 않음과 동시에 낙상 시 발생하는 엉덩이 충격힘을 크게 줄이므로, 낙상 고위험군이 많이 모여 있는 시설 내에 설치되어야 하는 바닥재로 평가된다.

6. 본 문헌 고찰의 제한점

본 연구의 제한점은 많은 데이터베이스 중에서 하나의 데이터베이스(PubMed)만 사용되었다는 것이다. PubMed는 의학분야에서 가장 흔하게 사용되는 데이터베이스이기 때문에 본 문헌 고찰 결과에 사실성이 보장된다고 할 수 있지만, 다른 데이터베이스를 통해 획득되는 증거들 또한 함께 고려해 보아야 한다.

7. 고찰 결과 요약

노인 낙상예방을 위한 통합적인 중재법의 방향성을 제시하기 위해, 현재까지 제시된 증거 기반 노인 넘어짐 및 고관절 골절 예방프로그램의 효과를 고찰하였다. 위에서 고찰한 바와 같이, 노인 낙상 예방을 위한 다섯 가지 중재방법은 연구방법에 따라 영향력의 차이는 있었지만, 모두 효과적이었다. 상기 고찰 결과는 효과적인 노인 낙상 예방 프로그램을 개발하는 데 도움을 줄 것이다.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

AUTHOR CONTRIBUTIONS

Conceptualization: WJC. Data curation: SL, SK, KL. Formal analysis: SL, SK, KL. Investigation: SL, SK, KL. Methodology: SL, SK, KL, WJC. Project administration: WJC. Resources: WJC. Supervision: WJC. Writing - original draft: SL, SK, KL, WJC. Writing - review & editing: WJC.

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