Untersuchung des Zusammenhangs von Anämie und Veränderungen in spatio-temporalen Gangparametern mit dem Sturzrisiko bei Senioren

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1 Publikationsliste

- Thaler-Kall K, Döring A, Peters A, Thorand B, Grill E, Koenig W, Horsch A, Meisinger C. Association between anemia and falls in community-dwelling older people: cross-sectional results from the KORA-Age study. BMC Geriatrics 2014, 14:29

- Thaler-Kall K, Peters A, Thorand B, Grill E, Autenrieth CS, Horsch A, Meisinger C. Description of spatio-temporal gait parameters in elderly people and their association with history of falls: results of the population-based cross-sectional KORA-Age study. BMC Geriatrics 2015, 15:32

2 Einleitung

2.1 Demographischer Wandel

In einer Gesellschaft, die durch medizinischen Fortschritt und ein gutes soziales System gekennzeichnet ist und somit immer älter wird, spielen medizinische Probleme des Alters eine immer größere Rolle [1]. Die Lebenserwartung ist in Deutschland wie auch in anderen Industrieländern in den letzten Jahren kontinuierlich gestiegen; so lag laut Statistischem Bundesamt die durchschnittliche Lebenserwartung von Frauen 1995 noch bei 79,78 Jahren und 2012 schon bei 83,14 Jahren; die von Männern stieg im gleichen Zeitraum von 73,24 auf 78,27 Jahre an. Im Gegensatz dazu ist die Geburtenrate gesunken: 2012 lag sie bei 1,38 Kinder pro Frau (im Alter von 15-49 Jahren) im Vergleich zu 2,37 im Jahre 1960. Dadurch ändert sich das Altersprofil der Bevölkerung zunehmend. Der Anteil an Personen über 65 ist in den letzten Jahren stetig gewachsen und wird auch in Zukunft noch ansteigen (Abbildung 1). Es ist prognostiziert, dass weltweit der Anteil an Personen über 65 Jahren zwischen 2004 und 2050 von 461 Millionen auf 2 Milliarden ansteigen wird [2, 3]. Für Deutschland wird geschätzt, dass der Anteil der über 60-jährigen in den nächsten 50 Jahren von gut 23% auf 37% steigen wird [4]. Außerdem ist interessant, dass die Restlebenserwartung einer über 65-jährigen Person jedes Jahr um 50 Tage steigt – Menschen verbringen immer mehr Zeit ihres Lebens im höheren Alter, d.h. als Senioren.

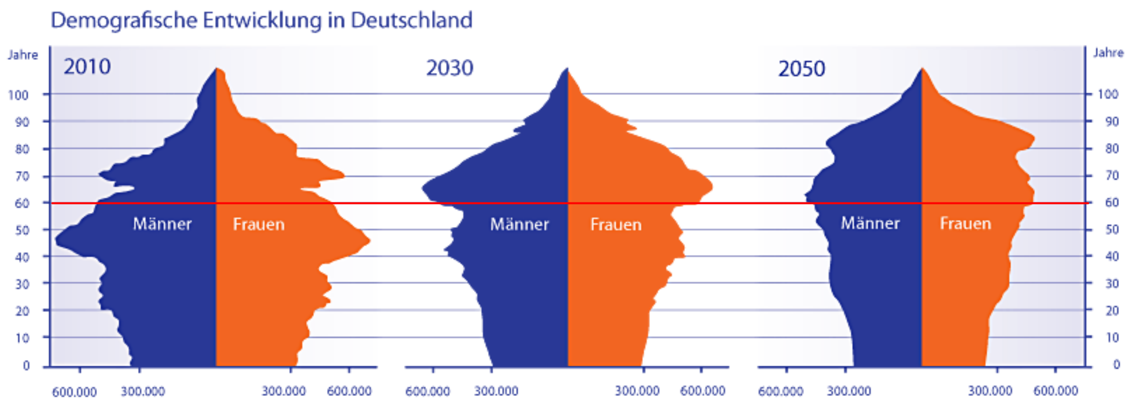

Abbildung 1: Der Wandel in der Altersstruktur von 1990 bis 2050: der Anteil der über 60-jährigen steigt kontinuierlich an. Quelle: Statistisches Bundesamt.

2.2 Multimorbidität bei Senioren

Senioren unterscheiden sich von jüngeren Menschen hinsichtlich ihres Gesundheitsprofils sowie in der Anzahl bestehender Krankheiten. Chronische Erkrankungen wie Diabetes mellitus oder Herz-Kreislauf-Erkrankungen treten bei jüngeren Menschen meist isoliert auf. Bei älteren Menschen jedoch treten häufig mehrere gesundheitliche Probleme gemeinsam auf – man spricht von Multimorbidität. Multimorbidität reduziert die Lebensqualität der Personen signifikant [5, 6] und sorgt für hohe Kosten im Gesundheitswesen [7]. In einer Publikation von Kirchberger et al. [8], die auf den Daten von 4127 in der Gemeinschaft lebenden Personen über 65 Jahren beruht, wurden 13 chronische Erkrankungen zur Definition der Multimorbidität herangezogen: Bluthochdruck, Erkrankungen der Augen, Herzerkrankungen, Erkrankungen der Lunge, der Niere, der Leber und der Gelenke, Diabetes mellitus, Krebserkrankungen, Schlaganfall, neurologische Erkrankungen, gastrointestinale und mentale Erkrankungen. Menschen, die mindestens zwei dieser Erkrankungen hatten, wurden als multimorbid eingestuft. Am häufigsten traten folgende Krankheitskombinationen auf: Bluthochdruck und Diabetes mellitus mit einer Odds Ratio (OR) von 2,95 und einem Konfidenzintervall (KI) von 2,19–3,96 sowie Bluthochdruck und Schlaganfall mit einer OR von 2,00 (KI [1,26–3,16]). In dieser Publikation wurden vier Multimorbiditätscluster identifiziert:

1. Kardiovaskuläre und metabolische Erkrankungen
2. Gelenk-, Leber-, Lungen- und Augenerkrankungen
3. Neurologische Erkrankungen
4. Gastrointestinale Erkrankungen und Krebserkrankungen.

Fast die Hälfte aller untersuchten Personen (44%) konnten einem dieser Muster zugeordnet werden, 14% sowohl dem ersten als auch dem zweiten Muster. Es konnte damit gezeigt werden, dass bestimmte Erkrankungen gehäuft gemeinsam auftreten – was auf zugrundeliegende pathologische Mechanismen hinweisen kann.

2.3 Gebrechlichkeit und Behinderung im Alter

Die steigende Lebenserwartung und die damit verbundene hohe Wahrscheinlichkeit einer bestehenden Multimorbidität bei Senioren werden den Unterstützungsbedarf und die Lebensjahre in Pflegebedürftigkeit ansteigen lassen. Man schätzt, dass bundesweit die Zahl der 2,25 Mio. Pflegebedürftigen (Stand 2007) auf etwa 3,37 Mio. im Jahr 2030 steigen wird [9]. Zusätzlich führt eine eingeschränkte körperliche und geistige Funktionsfähigkeit („Frailty“) sowie eine zunehmende Anzahl an Behinderungen („Disability“) zu einer Einschränkung der Lebensqualität. Senioren werden mit veränderten Lebensbedingungen, sozialer Isolation und fehlender Mobilität konfrontiert sein. Ein gesundes und „erfolgreiches“ Altern und die Aufrechterhaltung der persönlichen Autonomie trotz Einschränkungen im alltäglichen Leben sind daher relevante individuelle, politische und gesellschaftliche Ziele [10].

In einem systematischen Review von 2012 lag der Anteil an Personen über 65 Jahren mit „Frailty“ (klassifiziert nach den Kriterien von Fried [11]) bei 9,9% (95% KI 9,6-10,2), 44,2% wurden als „Pre-Frail“ eingestuft (95% KI 44,2-44,7). Frauen sind dabei häufiger betroffen als Männer und mit dem Alter steigt der Anteil von 4% bei den 65-69-jährigen bis auf 26% bei den über 85-jährigen [12]. „Frailty“ geht außerdem mit einer erhöhten Mortalität einher. Eine Studie mit 754 Teilnehmern zeigte, dass „Frailty“ in 27,9% der Fälle die Todesursache war [13].

In einer Publikation, die 4117 über 65-jährige Personen untersucht hat, lag der Anteil an minimalen Behinderungen bei 44,27%. Vor allem traten Behinderungen bei Frauen auf sowie bei Personen mit einem erhöhten Body Mass Index (BMI), einem niedrigen Einkommen, körperlicher Inaktivität und schlechter Ernährung. Probleme mit Gelenken und Augenerkrankungen beeinflussten die Behinderung am meisten [14]. Behinderung wurde dabei über den Health Assessment Questionnaire Disability Index (HAQ-DI) gemessen [15].

2.4 Stürze bei älteren Menschen

2.4.1 Definition von Stürzen

Es gibt keine allgemeingültige Definition des Begriffes „Sturz“ sondern mehrere Definitionen, die sich darin unterscheiden, ob die Person nach dem Sturz zwingend auf dem Boden liegen muss oder auch z. B. auf einem Möbelstück gelandet sein kann und ob auch durch äußere Einflüsse wie z. B. Erkrankungen hervorgerufene Stürze miteingeschlossen werden [16, 17]. Aufgrund dessen hat das Prevention of Falls Network Europe (ProFaNE) als Ergebnis einer Konsensuskonferenz aktuell die Verwendung folgender Definition empfohlen: „A fall should be defined as an unexpected event in which the participants come to rest on the ground, floor, or lower level.“ [18].

2.4.2 Folgen von Stürzen bei Senioren

Stürze sind ein weit verbreitetes Phänomen bei älteren Personen und können ein erfolgreiches Altern verhindern bzw. sogar zum Tode führen. Außerdem können Stürze die Ursache für langfristige Behinderungen sein. Jeder Dritte über 65-jährige Erwachsene stürzt einmal pro Jahr. Ungefähr jeder zehnte dieser Stürze bewirkt schwere Verletzungen, wie Kopfverletzungen oder Hüftbrüche [19-23].

Besonders schwerwiegende Folgen hat ein Sturz, wenn der Betroffene nicht selbstständig aufstehen kann und nicht sofort gefunden wird. Es gibt Studien, die zeigen, dass jede zweite Person, die nach einem Sturz länger liegen bleibt, innerhalb von einem halben Jahr stirbt [24, 25].

Doch selbst wenn Stürze nicht zum Tode führen, so bewirken sie häufig, dass ältere Menschen nicht mehr selbstständig leben können und im Heim untergebracht werden müssen. So zeigen Tinetti und Kollegen in ihrer Untersuchung an 1103 Personen zum Beispiel, dass 133 Personen (12,1%) nach einem Sturz in einem Heim untergebracht werden mussten [21]. Knochenbrüche treten in weniger als 10% der Fälle auf [22], können dann jedoch zu Morbidität und Einschränkungen über einen sehr langen Zeitraum führen. Aber auch Stürze ohne daraus resultierende direkte Folgen können die Lebensqualität und Mobilität älterer Menschen reduzieren, z. B. weil die Personen Angst davor haben, erneut zu stürzen.

Neben den gesundheitlichen Folgen und dem Einfluss auf die Lebensqualität der betroffenen Personen lösen Stürze auch hohe Kosten im Gesundheitswesen aus. In einem Review, der 32 weltweite Studien eingeschlossen hat, lagen die durch Stürze verursachten Kosten im Gesundheitswesen bei 0,85% bis 1,5% der gesamten Ausgaben im Gesundheitssektor und bei 113 bis 547 USD pro Person und Einwohner. Die Kosten pro gestürzter Person, pro Sturz und pro sturzbedingtem Krankenhausaufenthalt bewegten sich zwischen 2.044 und 25.955 USD, 1.059 und 10.913 bzw. 5.654 und 42.840 USD - je nach Schwere des Sturzes. 18 Analysen stammen aus den USA, neun aus Europa, vier aus Australien und eine aus Jamaika. Für Deutschland werden die Kosten für die Behandlung von Sturzfolgen auf 2,1 bis 3,8 Milliarden Euro pro Jahr geschätzt. Bisher gibt es allerdings noch keine Studien zu sturzbedingten Kosten in Deutschland; die genannten Zahlen basieren auf den Studien aus anderen Ländern [26].

2.4.3 Bekannte Risikofaktoren für Stürze bei Senioren

Aufgrund der oben dargestellten Erkenntnisse werden seit Jahren behandelbare Risikofaktoren für Stürze identifiziert. Viele verschiedene Risikofaktoren für Stürze wurden bereits 1988 von Tinetti und Kollegen identifiziert und 2010 in einer Metanalyse von DeAndrea et al. bestätigt. Hierzu gehören z. B. das Alter, ein bestehender Diabetes mellitus, eine manifeste Depression, kognitive Einschränkungen, funktionale Einschränkungen oder bereits vorangegangene Stürze [20, 27]. So fanden DeAndrea et al. in einer Analyse von 74 verschiedenen Untersuchungen heraus, dass die stärkste Assoziation zwischen vorangegangenen Stürzen und einem erhöhten Sturzrisiko bestand (OR = 2,8). Betrachtet man nur die Personen, die schon mehrmals gestürzt sind, so erhöht sich das OR auf 3,5. Ebenso erhöhten Gangprobleme das Sturzrisiko (OR = 2,1), wobei der Begriff Gangprobleme nicht genauer spezifiziert wurde. Auch die Verwendung von Gehhilfen (OR 2,2), ein bestehender Schwindel (OR = 1,8), eine Parkinsonerkrankung (OR = 2,7) und die Einnahme von Medikamenten gegen Epilepsie (OR = 1,9) erhöhten das Sturzrisiko. Die Messungen von Balance und Muskelschwäche variierten sehr stark zwischen den Studien, weshalb deren Einfluss auf das Sturzrisiko nicht genauer untersucht werden konnten [27].

Einige der identifizierten Risikofaktoren für Stürze wie z.B. Gleichgewichtsstörungen oder verminderte Kraft in den unteren Extremitäten könnten relativ einfach behandelt werden. Jedoch gibt es auch viele nicht beeinflussbare Risikofaktoren wie beispielsweise das Alter, bereits vorangegangene Stürze, das Geschlecht oder das Vorliegen von geistigen Behinderungen. Werden bei einer älteren Person solche nicht beeinflussbare Risikofaktoren identifiziert, so können vorbeugende Maßnahmen wie z. B. das Anbringen von Handläufen in den Wohnungen der Senioren oder die Installation eines Notrufsystems Stürze vermeiden bzw. die Folgen durch z. B. längeres Liegen nach einem Sturz verringern.

Auf der anderen Seite können Interventionen, die gezielt veränderbare Risikofaktoren für Stürze behandeln, das Sturzrisiko reduzieren. Deshalb macht es Sinn, weitere beeinflussbare Risikofaktoren für Stürze zu identifizieren, um in Zukunft die Sturzprävention weiter auszubauen zu können.

2.4.4 Anämie im Alter und Sturzrisiko

Ein niedriger Hämoglobinwert hängt - so wie Schwäche, Schwindel und chronische Erschöpfung - häufig mit einer Verschlechterung der Beweglichkeit, der physischen Funktionen und der exekutiven Funktionen[1] zusammen – all dies sind Faktoren, die das Sturzrisiko erhöhen können [28, 29]. Auf der anderen Seite hängen eine Einschränkung der Beweglichkeit sowie eine reduzierte Muskeldichte und Muskelkraft mit einem niedrigeren Hämoglobinwert zusammen [30, 31].

Verschiedene Publikationen haben einen Zusammenhang zwischen einer vorliegenden Anämie und einem erhöhten Sturzrisiko bei älteren Menschen, die zu Hause leben, in Altersheimen oder Krankenhäusern untergebracht sind, festgestellt. [32-35]. Eine weitere Studie, die sich nicht nur mit älteren Menschen sondern allgemein mit erwachsenen Amerikanern beschäftigt (REGARDS-Studie) fand heraus, dass bei Männern ein niedriger Hämoglobinwert mit einem erhöhten Sturzrisiko zusammenhing – bei Frauen ging sowohl ein niedriger als auch ein zu hoher Hämoglobinwert mit einem erhöhten Sturzrisiko einher [36]. Bei Patienten im Krankenhaus gilt Anämie ebenfalls als Risikofaktor für Stürze [37]. Es gibt bisher allerdings nur wenige Studien, die eine große Gruppe von Senioren aus der Allgemeinbevölkerung, die noch zu Hause leben und am öffentlichen Leben teilhaben, untersuchten. Keine der Studien analysierte bisher Daten aus Deutschland.

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[1] Mit dem Terminus **exekutive Funktionen** werden in der Hirnforschung und Neuropsychologie geistige Funktionen bezeichnet, mit denen Menschen (im weiteren Sinne: höhere Lebewesen) ihr Verhalten unter Berücksichtigung der Bedingungen ihrer Umwelt steuern. Als Synonym für dieses Bündel an Fähigkeiten werden oft auch die Begriffe ***„kognitive Kontrolle***“ oder ***„Supervisory Attentional System (SAS)“*** benutzt. (Quelle: Wikipedia)

2.4.5 Gangveränderungen im Alter und Sturzrisiko

„Gehen ist ein riskantes Geschäft. Ohne eine sekundengenaue Abstimmung würde ein Mensch flach auf das Gesicht fallen; tatsächlich steht er bei jedem Schritt, den er macht, am Rande einer Katastrophe“ [John Napier][38].

Wir brauchen mehrere Jahre unseres Lebens, um zu lernen wie wir gehen. Als Erwachsene gehen wir automatisch, doch im Alter wird das Gehen wieder zunehmend zu einer schwierigen Aufgabe, auf die wir unsere ganze Aufmerksamkeit richten müssen – dann kann schon eine kleine Ablenkung zu einem Sturz führen. Auch gesunde ältere Menschen haben gegenüber gesunden jungen Menschen einen veränderten Gang. Winter und Kollegen zeigten in ihrer Publikation, dass bei älteren Menschen z. B. die Geschwindigkeit und Doppelschrittlänge verkürzt waren [39], ein Ergebnis, das von Menz et al. bestätigt wurde [40].

Auch wenn die Ursache für einen Sturz sich aus vielen Faktoren zusammensetzt, haben doch die meisten Stürze etwas gemeinsam: sie treten während des Gehens auf [39-41]. Verschiedene Studien haben festgestellt, dass Veränderungen in spatio-temporalen Gangparametern das Sturzrisiko signifikant erhöhen – besonders Parameter, die die Gangvariabilität beschreiben, waren hier sehr aussagekräftig [42-44]. So stellte Maki in seiner Untersuchung digitalisierter Fußabdrücke von 75 Personen fest, dass eine reduzierte Doppelschrittlänge und Geschwindigkeit sowie eine verlängerte Doppelstandzeit zwar einen Einfluss auf die Angst zu stürzen jedoch keinen Einfluss auf das Sturzrisiko an sich haben. Die Schritt zu Schritt Variabilität der drei genannten Gangparameter war allerdings direkt assoziiert mit dem Sturzrisiko, wobei die Variabilität in der Geschwindigkeit am aussagekräftigsten war [44]. Hausdorff et al. konnten sogar zeigen, dass die Variabilität in der Doppelschrittdauer Stürze vorhersagen kann [43].

Die Messung solcher Gangparameter ist allerdings schwierig, die Veränderungen sind mit bloßem Auge normalerweise nicht zu erkennen. Deshalb ist der Einsatz von präzisen, objektiven Messmethoden für Gangparameter in der Sturzprävention nötig. Bei Hausdorff et al. z. B. bewegten sich die Studienteilnehmer 6 Minuten lang während sie Drucksensoren in ihren Schuhen trugen [43]. Beispiele für andere heute verwendete Systeme zur Messung von Gangparametern sind opto-elektronische Systeme, Druckmessplatten, Akzelerometer oder elektronische Gangmatten. Jede dieser Methoden hat Vor- und Nachteile. So erlauben Akzelerometer oder in den Schuh integrierte drahtlose Sensoren auch Langzeitmessungen des Ganges, können aber den Gang nicht so genau bewerten wie zum Beispiel die Messung über Gangmatten. Mittels Gangmatten können jedoch jeweils nur wenige Schritte aufgenommen werden [45].

Die Daten, die in dieser Arbeit untersucht wurden, wurden mithilfe einer elektronischen Gangmatte (GAITRite System) gemessen, über die die Studienteilnehmer gehen mussten. Die Matte zeichnete auf einer Strecke von 4,88 Metern über Drucksensoren die einzelnen Bodenkontakte der Personen auf und errechnete sowohl temporale Parameter wie die Schrittdauer oder die Anzahl der Schritte pro Minute als auch spatiale Parameter wie die Schrittlänge oder Schrittweite. Für unsere Untersuchungen haben wir uns auf sechs Parameter beschränkt: Geschwindigkeit, Kadenz (Schritte/Minute), Dauer, Doppelschrittlänge, Doppelschrittdauer und Schrittweite.

Es stellt sich die Frage, ob es typische, primär, d.h. mit bloßem Auge, nicht erkennbare Veränderungen im Gang von älteren Menschen gibt, die auf ein erhöhtes Sturzrisiko hindeuten. Deren Erkennung könnte dabei helfen, Stürzen vorzubeugen. Außerdem wäre es interessant zu sehen, wie sich der Gang im Zusammenhang mit den oben erwähnten Themen Multimorbidität, „Frailty“ und „Disability“ verändert.

2.4.6 Stand der Forschung hinsichtlich Sturzhäufigkeit und Sturzrisiko bei älteren Menschen aus der deutschen Allgemeinbevölkerung

Für Deutschland liegen bisher weder Studien mit bevölkerungsbasierten Stichproben noch Statistiken zur Häufigkeit von Stürzen vor [46]. Nur die Daten der Krankenhäuser zur Behandlung von Verletzungen infolge von Stürzen geben einen Aufschluss über die Größe des Problems. Demnach werden jährlich ca. 1,7 Millionen Patienten wegen Verletzungen, Vergiftungen und anderen Folgen äußerer Ursachen zur stationären Behandlung aufgenommen. Bei den Personen über 65 Jahren ist die Fallzahl dabei am größten: pro Jahr treten 3726 Fälle je 100.000 Einwohner auf [4].

Zwei Studien beschäftigten sich bisher mit zu Hause lebenden Senioren in Deutschland. In der einen Untersuchung wurden 217 mindestens 70-jährige Senioren rekrutiert. 29-39% dieser Personen berichteten, im vergangenen halben Jahr mindestens einmal gestürzt zu sein. Während des 12-monatigen Untersuchungszeitraum stürzten 45% der Senioren [47].

In der anderen Studie, bei der 192 über 65-jährige Personen beobachtet wurden, wurde bei 60% der Teilnehmer ein Sturz beobachtet. Der Unterschied lag hierbei in der Rekrutierung: in der zweiten Studie wurden die Teilnehmer über ambulante Pflegedienste und eine geriatrische Klinik rekrutiert und hatten dabei vermutlich schon von vorneherein ein höheres Sturzrisiko [48].

Im Bereich der stationären Versorgung werden für Deutschland jährlich Daten zur Sturzhäufigkeit erhoben [49]. Bei den über 65-jährigen Personen ist die Rate des ersten Sturzes pro 1000 Behandlungstage im Krankenhaus (4,2 bis 4,7) ähnlich der im Pflegeheim (4,5 bis 5,1). Betrachtet man aber die jüngeren

Personen, so ist die Rate mit 5,3 Stürzen pro 1000 Behandlungstage im Krankenhaus fast doppelt so hoch wie in Pflegeheimen (2,8). Der Anteil an gestürzten Personen ist in geriatrischen Abteilungen am größten (6,3 bis 7,2 %) [46].

Bezüglich Sturzrisiken in der Allgemeinbevölkerung gibt es bisher keine speziell mit deutschen Daten erhobenen Ergebnisse.

2.5 Zielsetzung und Inhalt dieser Dissertation

In dieser Arbeit sollten anhand von Daten einer bevölkerungsbasierten Querschnittsstudie (KORA Age) mögliche Risiken für Stürze bei älteren in Deutschland lebenden Personen untersucht werden. Die daraus gewonnen Ergebnisse lieferten neue Informationen über Sturzhäufigkeit und Sturzrisiken von Senioren in Deutschland. Der Fokus lag dabei auf der Untersuchung des Zusammenhanges der Risikofaktoren Anämie und veränderten Gangparametern mit dem Auftreten von Stürzen.

Im Rahmen der KORA Studie (Kooperative Gesundheitsforschung in der Region Augsburg) wird seit über 20 Jahren der Gesundheitszustand von Personen aus der Allgemeinbevölkerung in der Region Augsburg untersucht. Insgesamt wurden 4 populationsbasierte Querschnittserhebungen zwischen 1984/85 und 1999/2001 durchgeführt, 3 davon waren Teil des WHO-MONICA-Projektes; nach Ende dieses Projektes 1995 wurde die vierte Erhebung vom Helmholtz Zentrum als KORA Projekt weitergeführt. Die Stichproben wurden als Zufallsauswahl aus den Einwohnermeldeämtern erhoben. Einschlusskriteriien waren die deutsche Staatsangehörigkeit und ein Wohnsitz in der Region Augsburg (Stadt Augsburg und die beiden angrenzenden Landkreise Aichach-Friedberg und Augsburg). Teil dieser Studie ist das Projekt KORA Age, auf dem die dieser Dissertation zugrunde liegenden Analysen beruhen. Die Verbundpartner Helmholtz Zentrum München, Technische Universität München, Ludwig-Maximilians-Universität München und Klinikum Augsburg entwickelten dafür ein spezielles Untersuchungsprogramm, das die Teilnehmer hinsichtlich ihres Gesundheitszustandes und ihrer Lebensumstände klassifiziert. Die Veränderung von Gesundheitsparametern von Menschen über 65 Jahren wurde dabei über einen Zeitraum von 3 Jahren erforscht. Ziel war es, die Determinanten von Multimorbidität zu untersuchen und Faktoren für ein „erfolgreiches Altern“ zu identifizieren. Dazu wurden 2009 aus 9197 möglichen Teilnehmern, 5991 Personen kontaktiert (Voraussetzung: lebend und erreichbar). Von diesen nahmen 4127 Personen an einem standardisierten telefonischen Interview teil. Eine Substichprobe von 1079 Personen wurde für eine ausführliche Untersuchung in das Studienzentrum in Augsburg eingeladen.

In der ersten Publikation aus dieser Arbeit geht es um den Einfluss von Anämie auf das Sturzrisiko. Anhand von Daten aus der Querschnittsstudie KORA Age 1 wurde der Zusammenhang von Anämie und einem erhöhten Sturzrisiko bei über 65-jährigen Personen analysiert. Die untersuchte Gruppe bestand aus 967 Personen, die noch zu Hause lebten. Am Tag der Untersuchung wurde von jedem Probanden einen Blutprobe genommen und der Hämoglobin-Wert bestimmt. Außerdem wurden die Probanden gefragt, ob und wie oft sie im letzten Jahr gestürzt sind. Der Anteil an Personen, die im letzten Jahr gestürzt waren, lag bei 14%, Frauen stürzten fast doppelt so häufig (19,1%) wie Männer (10,6%). Im Gegensatz zu bereits bekannten Publikationen konnte in unserer Untersuchung kein grundsätzlicher Zusammenhang zwischen Anämie bzw. einem erniedrigten Hämoglobin-Level und dem Sturzrisiko festgestellt werden. Allerdings konnte bei Untersuchungen von höheraltrigen Personen mit „Frailty“ (nach Stanford Health Assessment Questionnaire [15]) ein additiver Effekt der Anämie in Bezug auf das Sturzrisiko festgestellt werden. Aufgrund unseres Studiendesigns ist es jedoch nicht möglich, kausale Zusammenhänge zwischen Anämie und Stürzen festzustellen.

In der zweiten Publikation wurden die Unterschiede von verschiedenen Gangparametern in folgenden Personengruppen der in 2009 gemessenen Daten untersucht:

- gebrechliche und nicht gebrechliche Personen („Frailty“)
- multimorbide und nicht multimorbide Personen
- behinderte und nicht behinderte Personen („Disability“)
- Männer und Frauen
- „junge“ Senioren (65 bis 74) und „alte“ Senioren (75+)
- Personen, die im letzten Jahr gestürzt sind und Personen, die nicht gestürzt sind
- Personen, die in der letzten Woche weniger als fünf oder mindestens fünf verschiedene Medikamente eingenommen hatten

Bis auf die Untersuchung der Sturz/Nicht Sturz – Gruppe unterschieden sich alle untersuchten Gangparameter (Geschwindigkeit, Kadenz (Schritte/Minute), Dauer, Doppelschrittlänge, Doppelschrittdauer und Schrittweite) in allen Gruppen signifikant. Gebrechliche, multimorbide, behinderte und ältere Menschen laufen langsamer mit weniger Schritten pro Minute, machen kürzere Schritte und haben einen breiteren Gang. Dasselbe gilt für die Personen, die mindestens 5 Medikamente eingenommen hatten – sehr wahrscheinlich ist diese hohe Medikamentenanzahl eine Folge des

Gesundheitszustandes der Probanden. Frauen hatten im Gegensatz zu Männern einen schmäleren Gang und bewegten sich langsamer mit weniger Schritten pro Minute und kürzeren sowie schnelleren Schritten.

Für die Gruppe Sturz/Nicht-Sturz wurden zusätzlich logistische Regressionsmodelle für den Einfluss der Gangparameter auf das Sturzrisiko berechnet. Hier konnte gezeigt werden, dass bei älteren Männern (75+) eine erhöhte Schrittanzahl und eine verkürzte Schrittlänge auf ein erhöhtes Sturzrisiko hinweisen. Die Geschwindigkeit hingegen zeigte keine signifikanten Zusammenhänge mit dem Sturzrisiko. Ebenso konnten für Frauen keine signifikanten Einflüsse der fünf Gangparameter auf das Sturzrisiko festgestellt werden.

Beide Publikationen zeigen interessante neue Erkenntnisse bezüglich des Zusammenhangs zwischen Anämie und Stürzen, zwischen Gangparametern und dem allgemeinen Gesundheitszustand von älteren Männern und Frauen, sowie Gangparametern und Stürzen. Allerdings erlaubt das Studiendesign einer Querschnittsstudie keinerlei Aussagen zu kausalen Zusammenhängen zwischen jeweiligem Risikofaktor und Stürzen. Die Ergebnisse erlauben aber die Empfehlung, den allgemeinen Gesundheitszustand von Senioren detailliert zu untersuchen und bei Hinweisen auf Gebrechlichkeit, Behinderung oder Multimorbidität vorbeugende Maßnahmen zur Sturzvermeidung zu treffen. So können schwerwiegende Verletzungen durch Stürze und sogar Todesfälle vermieden werden. Die vorliegende Arbeit beschäftigt sich mit in Deutschland erfassten, populationsbasierten Daten und liefert hier erste Ergebnisse zur Sturzhäufigkeit bei zu Hause lebenden Senioren.

3 Zusammenfassung

Mit dem Anstieg der Lebenserwartung und dem Abfall der Geburtenrate ändert sich die Zusammensetzung der Gesellschaft in Deutschland: Der Anteil der Senioren steigt. Da die gesundheitlichen Probleme von Senioren andere sind als die von jüngeren Menschen, erfordert dies Anpassungen im Gesundheitswesen. So treten bei Senioren häufig mehrere Erkrankungen gemeinsam auf, man spricht von Multimorbidität. Die verlängerte Lebenserwartung verursacht außerdem einen erhöhten Pflegebedarf bei Gebrechlichkeit und Behinderung.

Ein weiteres großes Thema in der geriatrischen Medizin sind Stürze. Diese bilden sowohl aufgrund der gesundheitlichen Folgen für die Betroffenen als auch aufgrund der dadurch entstehenden hohen wirtschaftlichen Kosten ein zunehmendes Problem für die Gesellschaft. So können Stürze zu schwerwiegenden Verletzungen bis hin zum Tode führen. Die Identifikation von behandelbaren Risiken für Stürze gewinnt deshalb an Bedeutung.

Die vorgelegte Arbeit untersucht den Zusammenhang zwischen Anämie und Veränderungen im Gang eines Menschen mit dem Sturzrisiko dieser Person. Die Datenbasis bildeten sowohl Interviewdaten als auch Untersuchungsdaten von 967 zu Hause lebenden Personen, die älter als 64 Jahre waren. Die Daten stammen aus der KORA Studie, eine Studie, die seit über 20 Jahren den Gesundheitszustand der Bevölkerung der Region Augsburg untersucht.

Es konnte kein signifikanter Zusammenhang zwischen Anämie und Stürzen festgestellt werden. Jedoch konnte ein additiver Effekt der Anämie auf das Sturzrisiko in der Gruppe der gebrechlichen und behinderten Senioren festgestellt werden.

Die Untersuchung der Gangparameter lieferte die Erkenntnis, dass gebrechliche, multimorbide, behinderte und ältere Menschen langsamer und mit weniger Schritten pro Minute laufen. Außerdem machen sie kürzere Schritte und haben einen breiteren Gang. Dasselbe gilt für die Personen, die mindestens 5 Medikamente eingenommen hatten – sehr wahrscheinlich ist diese hohe Medikamentenanzahl eine Folge des Gesundheitszustandes der Probanden. Frauen hatten im Gegensatz zu Männern einen schmäleren Gang und bewegten sich langsamer mit weniger Schritten pro Minute und kürzeren sowie schnelleren Schritten. Außerdem konnte gezeigt werden, dass bei älteren Männern (75+) eine erhöhte Schrittanzahl und eine verkürzte Schrittlänge auf ein erhöhtes Sturzrisiko hinweisen. Die Geschwindigkeit hingegen zeigte keine signifikanten Zusammenhänge mit dem Sturzrisiko.

Zusätzlich beschreibt diese Arbeit zum ersten Mal das Sturzverhalten einer Gruppe von älteren zu Hause lebenden Personen aus der deutschen

Allgemeinbevölkerung. Der Anteil an Personen, die im letzten Jahr gestürzt sind, lag dabei bei 10,4% bei den Männern und 16,6% bei den Frauen.

Aufgrund des Studiendesigns können keine kausalen Aussagen zu untersuchten Faktoren und dem damit verbundenen Sturzrisiko getroffen werden. Die hier vorliegenden Ergebnisse beschreiben aber eine Gruppe von deutschen Senioren detailliert und geben Hinweise darauf, dass es sinnvoll ist, bei Anzeichen von Multimorbidität, Gebrechlichkeit oder Behinderung erste vorbeugende Maßnahmen zur Sturzprävention zu ergreifen.

4 Summary

Today, the percentage of older people (65 and older) of the German society increases due to an extending life expectancy and a decreasing birth rate. Whereas diseases appear isolated in younger people, older people do often suffer from so called multimorbidity where different diseases occur at the same time. The longer life expectancy also extents the need for home and outpatient care caused by frailty and disability.

Another serious problem in geriatrics are falls. They emerge as a big challenge for the society because of serious health consequences for the affected person as well as high economical costs. Falls can lead to serious injuries and even to death. The identification for treatable risk factors therefore gains importance.

This work investigates on the relationship between anemia and changes in the gait of a person and their risk to fall. Data were collected via interviews or physical examinations of 967 community-dwelling people aged 65 and older. The data were collected during the KORA study, which analyses the health status of the population of the region Augsburg (Germany) since 20 years.

In this data no significant relationship between anemia and falls were found. But an additive effect of anemia on the fall risk in the frail and disabled group was found. Furthermore the analysis of gait parameters showed, that frail, multimorbid, disabled and older people walk slower, with less steps per minute, shorter steps and a wider gait. The same applies for people which take five or more drugs regularly – something which is probably caused by the health status of a person. Women have a decreased gait width compared to men; they walk slower with fewer steps per minute and make shorter, faster steps. It was also shown that the fall risk increases with an increasing step number and decreasing step length in men aged 75 and older. There was found no significant relationship between speed and fall risk.

Additionally this work is the first to describe falls in elderly, community-dwelling, German people: 10.4% of all men and 16.6% of all women aged 65+ did fall at least once during the last year.

The study design did not allow us to give evidence to some causal correlations regarding the analyzed risk factors. But the results describe a group of German seniors in detail and imply to take fall prevention measures in case one finds indications of multimorbidity, frailty or disability in seniors.

5 Publikation 1: Association between anemia and falls in community-dwelling older people: cross-sectional results from the KORA-Age study

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Association between anemia and falls in community-dwelling older people: cross-sectional results from the KORA-Age study

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Abstract

Background: Falls and fractures are among the principal causes of disability, and mortality of older people. Therefore, identifying treatable risk factors for falls in this population is very important. Here we evaluate the association between anemia and falls in community-dwelling people aged 65 years and older.

Methods: In 2009 967 community-dwelling people aged 65 years and older were included as part of the KORA-Age study. History of falls was assessed via questions derived from the National Health and Nutrition Examination Survey questionnaire. A non-fasting venous blood sample was obtained from all study participants. Anemia was defined as a hemoglobin level below 12 g/dL in women and below 13 g/dL in men according to the WHO criteria. Different logistic regression models were computed including relevant confounders such as sex, age, and disability to estimate Odds Ratios (OR) for falls.

Results: In the total sample there was no significant association between anemia and falls neither in the unadjusted (OR 1.35; 95% CI 0.87-2.09) nor in the multivariable-adjusted models (OR 1.06; 95% CI 0.66-1.70). The association between continuous hemoglobin levels and falls was significant in the unadjusted model (OR per 1 SD decrease 1.36; 95% CI 1.14-1.64), but after adjustment for age and sex the association was attenuated and lost its significance (OR 1.13; 95% CI 0.92-1.38). In age- and sex-stratified analyses, no significant associations between anemia or hemoglobin levels and falls could be found. However, in joint analysis in the total sample a significantly, more than two-fold increased risk was observed after multivariable adjustment in persons with anemia and disability (OR 2.10; 95% CI 1.12-3.93) in comparison to persons without anemia and disability.

Conclusions: In the present study we have not found an independent association between hemoglobin levels or anemia and falls in older people from the general population. Because there was an additive effect of anemia and disability on the occurrence of falls, blood count should be measured in disabled older men and women to identify persons, who are at particular high risk for falls.

Background

Falls and fall-related injuries are considered a major public health problem in older people. Thirty percent of people aged 65 plus experience a fall at least once a year, and 15% at least twice per year [1-3]. It has been well established knowledge that falls and fractures are among the principal causes of disability, admission to hospital care, and mortality in older people [4-6]. Due to the inability to get up again without help, older people sometimes do experience a "long lie" [7], thus further aggravation of injuries occurs. It has been shown that half of older people who did lie longer after having fallen, die within 6 months [7,8]. Falls are also associated with high costs. For Germany, Heinrich et al. estimated overall attributable costs between 2.1 and 3.8 billion Euros per year [9]. Due to these serious health and economic consequences, the identification of treatable risk factors for falls of older people is important.

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Anemia is common in old age, with a prevalence of approximately 11% in subjects aged 65 years and older as documented in the Third National Health and Nutrition Examination Survey (NHANES III) study. The prevalence of anemia increases rapidly after the age of 50, approaching a rate greater than 20% in those individuals aged 85 years or older [10]. This also has been confirmed by the Leiden 85 plus study, in which the prevalence of anemia has been 26.7% for people aged 85 years or older [11]. Regarding sex differences the results of the NHANES III study showed almost no difference in the group of 65 to 74 years (7.8% in men vs. 8.5% in women), yet with increasing age, the prevalence of anemia was much higher in men than in women (26.1% vs. 20.1%; aged 85+) [10]. In the Leiden 85 plus study the difference was even higher: 35.5% anemic males vs. 22.3% anemic females [11].

Recently, anemia in old age, defined as a hemoglobin level below 12 g/dL in women and below 13 g/dL in men [12], has received increasing attention among researchers. Symptoms of anemia include low energy, fatigue, dizziness, and general weakness. In addition, late life anemia is associated with subsequent physical decline, as illustrated by increased disability, impaired performance, and muscle weakness [13,14]. With these consequences, anemia could result in an increased risk of subsequent falls, although research confirming such a potential link is limited.

So far, only a few publications exist investigating the relation of anemia and falls in older persons. Three studies found a significant increase in risk of falls with decreasing hemoglobin (Hb) levels [15-17]. One other could not find a significant relation, but points out that anemic people fall more often than non-anemic people [18]. Two of these publications included only people living in nursing homes [15] or hospitalized for acute care [17], and two others included community-dwelling people with conflicting results [16,18].

Therefore, the aim of this study was to analyze the association between anemia and falls in 967 community-dwelling men and women aged 65 years or older. Furthermore, we examined the combined relationship of anemia and disability as well as frailty with falls in older people.

Methods

Study design and participants

Data were collected in 2009 during the KORA (Cooperative Health Research in the Region of Augsburg)-Age study, a follow-up study of the four MONICA/KORA Augsburg Surveys [19]. People aged 65 years and older were taken from a population based random sample (n = 5,991). In total, 4,127 people participated in a standardized telephone interview (response 67%). Out of this group a randomly drawn sample of 1,079 participants additionally underwent extensive physical examinations including the registration of drug intake, collection of blood samples, anthropometric examination, grip force measurement, gait analysis, and an additional interview amongst others. Blood samples and answers to fall questionnaires were available for 1,048 participants. After exclusion of 81 participants because of missing data the final data set for the present analysis consisted of 967 participants (477 women and 490 men) aged 65–91 years. The study was approved by the ethics committee of the "Bayerische Landesärztekammer"; all participants provided a written informed consent.

Outcome definition

History of falls was assessed with the question "Did you fall in the previous year?" with possible answers "yes, once", "yes, more than once" and "no". This variable was dichotomized in "at least one fall" and "no fall". The question was derived from the National Health and Nutrition Examination Survey (NHANES)-questionnaire [20].

A non-fasting venous blood sample was obtained from all study participants while sitting. Hematological parameters were determined from fresh venous EDTA blood samples using impedance measurements (Coulter® LH 780, Beckman Coulter GmbH, Krefeld, Germany). Anemia was defined according to WHO criteria as a hemoglobin (Hb)-level less than 12 g/dL in women and less than 13 g/dL in men [12].

Covariables

Information on socio-demographic characteristics and lifestyle behavior was collected by an interview. Frailty was assessed according to the criteria of Fried et al. [21]: weight loss in the last 6 months (short German SCREEN II questionnaire [22]), fatigue (via interview questions), low physical activity (via interview questions [23]), low walking speed (Timed Up and Go Test) and low grip force (measured via JAMAR, Saehan Corp.). Participants were classified as frail when they met 3 or more criteria, pre-frail when they met 1 or 2 criteria and non-frail when no criterion was met. The variable was dichotomized in "frail" (including pre-frail) and "non-frail". The disability score was assessed via the Stanford Health Assessment Questionnaire [24] and categorized as disability "yes" (score ≥0.5) or "no" (score <0.5) as suggested in literature [25]. Multimorbidity was obtained with the Charlson-Comorbidity-Index from Chaudhry [26]. Participants were classified as multimorbid, if they had ≥3 diseases. Drug intake during the last 7 days before the examination was recorded with the IDOM-Software [27].

Statistical analyses

Besides descriptive analyses, different logistic regression models were computed to assess associations of anemia/

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hemoglobin values with falls, respectively. Hemoglobin levels were considered as continuous variable (decrease per SD) and anemia (yes/no) was defined via WHO criteria [12].

Variables were considered as confounders in the multivariable regression model, if they were significantly ($p < 0.05$) related to falls as well as Hb-level/anemia after adjustment for age and sex (for details see Table 1). However, the number of drugs was considered as confounder although it was not significantly related to falls, because the relation to anemia and Hb-level was significant and literature suggests it as one risk factor for falls [28-30].

For the outcome "falls (yes/no)" the unadjusted model included hemoglobin level or anemia as independent variables. Model 1 additionally included age (continuous), and sex (in the unstratified analyses only) as confounders. In model 2, the number of drugs was added in addition to the confounders of model 1. In model 3 the variable "disability status (yes/no)" was added to the confounders of model 2.

We stratified all models by sex, as the normal Hb-level for men (≥13.0 g/dL) is higher than for women (≥12.0 g/dL) and due to the differences regarding the frequency of falls among men and women. We also stratified all models by age groups. The group of "young-old" included participants aged 65 to 74 years; the group of the "old-old" included all participants aged 75 years and older. Linearity was checked by including a quadratic term of the hemoglobin variable in the models (total study sample). As the p-values of the quadratic terms were not significant, linearity was assumed for the parameter hemoglobin.

Table 1 Overview of p-values for considered confounders

	Hb level	Anemic-WHO [12]	Falls
Multimorbidity	0.0049	0.0118	0.1334
Disability	0.0023	<.0001	0.0038
Diuretics	0.0584	0.0318	0.6326
Frailty	<.0001	<.0001	0.1866
Hypertension	0.1297	0.8939	0.2585
Diabetes	0.0004	0.0369	0.4392
Anticoagulants	0.2342	0.0625	0.2856
Antihypertensives	0.1361	0.0553	0.9232
Number of drugs	<.0001	<.0001	0.3257
Nutrition score	0.7864	0.1241	0.0044
Elevated alcohol intake*	0.0004	0.0702	0.4226
PASE†	0.7922	0.2476	0.7308
BMI	0.0012	0.0689	0.0274

*alcohol intake >24 g/day in men and >12 g/day in women.
†Physical Activity Scale for the Elderly. Scores range from 0 to 361 [31].

To examine the joint effect of anemia and disability as well as frailty on the occurrence of falls, in a second step combined anemia and disability and anemia and frailty variables were created. The subjects were classified into four categories: 1. anemia "yes" and disability (frailty) "yes", 2. anemia "yes" and disability (frailty) "no", and 3. anemia "no" and disability (frailty) "yes". Those with no anemia and no disability (frailty) were category 4 and thus the reference group. These analyses were performed in the total sample but not conducted separately for men and women or for the two age-groups due to low numbers in the different subgroups.

Results of the models were presented as Odds Ratios (ORs) and corresponding 95% confidence intervals (CIs). Significance tests were two tailed and p-values ≤0.05 were considered as statistically significant. All analyses were performed with SAS (version 9.2, SAS Institute Inc, Cary, NC, USA).

Results

Study sample characteristics by sex

Table 2 presents the study characteristics of the study population by sex. A total of 967 participants were included accounting 477 women and 490 men. The mean Hb-level was significantly higher in males than in females (14.0 vs. 13.0 g/dL, $p < .0001$). Also mean hematocrit was higher in men than in women. Women fell nearly twice as often as men. When determining the anemia status via WHO criteria (Hb-level <12 g/dL in female, Hb-level <13 g/dL in male) [12], 17.7% of all participants were classified as anemic. The percentage was higher in men, but differed not significantly from women. Altogether 30.8% of the examined women were disabled; the corresponding number in men was 19.6%. Other significant differences between men and women could be found for nutrition score (39.0 vs. 37.5), percentage of elevated alcohol intake (30.2% vs. 24.5%) and for the mean PASE value (124.7 vs. 113.9).

Fall and non-fall-participant characteristics

Table 3 documents the study characteristics for participants who fell (fallers) as well as participants who reported no fall during the last year (non-fallers). In the total sample fallers were significantly older than non-fallers; the same could be found when analyzing men and women separately. Fallers also had lower values of hemoglobin and hematocrit in the total sample, but not in the sex-stratified groups. The percentage of anemic persons in the whole sample was higher for fallers than for non-fallers (21.2 vs. 17.0%); this was also the case when stratifying by sex, but the differences were not statistically significant. Significantly more fallers were frail and disabled. The nutrition score was significantly lower in fallers compared to non-fallers in the total sample.

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Table 2 Study sample characteristics by sex (n (percentages) or means (±SD)

Variable	Males (n = 490)	Females (n = 477)	All (n = 967)	P value
Mean age, y	75.9 (6.4)	76.0 (6.6)	76.0 (6.5)	0.7831*
Falls, n (%)	52 (10.6%)	91 (19.1%)	143 (14.0%)	0.0002†
Anemia-WHO [12] n (%)	96 (19.6%)	75 (15.7%)	171 (17.7%)	0.1149†
Mean hemoglobin, g/dL	14.0 (1.3)	13.0 (1.0)	-	<.0001*
Mean hematocrit, %	41.0 (3.8)	38.3 (3.0)	-	<.0001*
Multimorbidity, n (%)	44 (9.0%)	38 (8.0%)	82 (8.5%)	0.5718†
Disability, n (%)	91 (18.6%)	147 (30.8%)	238 (24.6%)	<.0001†
Frailty, n (%)	205 (41.8%)	196 (41.1%)	401 (41.5%)	0.8137†
Hypertension, n (%)	367 (74.9%)	359 (75.3%)	726 (75.1%)	0.8959†
Diabetes, n (%)	87 (17.8%)	80 (16.8%)	167 (17.3%)	0.6858†
Use of diuretics, n (%)	226 (46.1%)	204 (42.8%)	430 (44.5%)	0.2939†
Use of anticoagulants, n (%)	40 (8.2%)	38 (8.0%)	78 (8.1%)	0.9105†
Use of antihypertensives, n (%)	336 (68.6%)	328 (68.8%)	664 (68.7%)	0.9488†
Use of ≥5 prescribed drugs, n (%)	156 (31.8%)	149 (31.2%)	305 (31.5%)	0.8409†
Mean nutrition score	39.0 (5.1)	37.5 (5.4)	38.3 (5.3)	<.0001*
Elevated alcohol intake, n (%)**	148 (30.2%)	117 (24.5%)	265 (27.4%)	0.0479†
Mean PASE††	124.7 (60.4)	113.9 (48.9)	119.4 (55.2)	0.0025*
Mean BMI kg/m^2	28.4 (3.9)	28.4 (4.6)	28.4 (4.2)	0.9249*

*t-test.
†Chi-square test.
**alcohol intake >24 g/day in men and >12 g/day in women.
††Physical Activity Scale for the Elderly. Scores range from 0 to 361 [31].

When stratifying by sex, differences were still significant among women, but in men only the difference regarding the proportion of disabled persons was statistically significant. In the total sample fallers had a significantly lower BMI than non-fallers, but these differences were not significant in both men and women. In women, the percentage of multimorbidity was significantly higher among fallers than among non-fallers.

Logistic regression analysis

In the logistic regression models no independent association between hemoglobin levels or anemia and falls could be found. Detailed results for the different logistic regression models are provided in Table 4. In the total sample there was a significant association between hemoglobin levels and falls only in the unadjusted model (OR per 1 SD decrease 1.36; 95% CI 1.14-1.64). After adjustment for age and sex, the association already lost significance. In age- and sex-stratified analyses also no independent association between hemoglobin levels and falls could be found.

When examining the association between anemia and falls no significant relationship was found, either in the unadjusted or in the confounder-adjusted models (Table 4). This could be shown for the whole group as well for women and men and both age-groups (young-old and old-old) in the stratified analyses.

Combined analyses

The joint relationships between anemia and disability as well as frailty for the total sample are also shown in Table 4. Men and women without anemia and without disability (frailty) were the reference group. Persons with anemia and disability showed the strongest association with falls in comparison to the reference group, even after adjustment for age, sex and number of drugs (OR 2.10; 95% CI 1.12-3.93). The corresponding OR was 1.61 (95% CI 1.00-2.58) in disabled participants without anemia; however, persons with anemia but without disability had no significantly increased OR for falls compared to the reference group. The joint associations of anemia and frailty showed also an increased odd of falls in the unadjusted analysis across the 4 categories with the highest odds in persons with anemia and frailty in comparison to the reference group. After further adjustment, these associations were attenuated and became non-significant (see Table 4).

Discussion

In the present analysis including 967 community-dwelling elderly men and women no significant association between hemoglobin levels or anemia and falls could be found. Thus, the suggestion that anemia is an independent risk factor of falls in elderly people from the general population could not be supported by these

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Table 3 Fall and non-fall-participant characteristics (percentages or means (±SD))

Variable	Fall participants (n = 143)			Non fall participants (n = 824)			p-value (*t*-test/Chi-square test)		
	All	Male (n = 52)	Female (n = 91)	All	Male (n = 438)	Female (n = 386)	All	Male	Female
Mean Age, y	78.3 (7.3)	78.0 (7.5)	78.4 (7.2)	75.6 (6.3)	75.7 (6.2)	75.5 (6.3)	<.0001	0.0368	0.0004
Mean hemoglobin, g/dL	13.2 (1.2)	13.7 (1.4)	12.9 (0.9)	13.6 (1.3)	14.0 (1.3)	13.1 (1.1)	0.0005	0.1592	0.0880
Anemia,% [12]	21.7	28.9	17.6	17.0	18.5	15.3	0.1750	0.0753	0.5881
Mean hematocrit, %	38.8 (3.4)	40.4 (3.9)	37.9 (2.7)	39.8 (3.7)	41.1 (3.7)	38.4 (3.1)	0.0014	0.2190	0.1529
Multimorbidity, %	12.6	11.5	13.2	7.8	8.7	6.7	0.0561	0.4948	0.0409
Disability, %	41.3	34.6	45.1	21.7	16.7	27.5	<.0001	0.0017	0.0011
Frailty, %	52.5	46.2	56.0	39.6	41.3	37.6	0.0039	0.5045	0.0013
Hypertension %	72.7	82.7	67.0	75.5	74.0	77.2	0.4815	0.1704	0.0431
History of diabetes %	16.1	19.3	14.3	17.5	17.6	17.4	0.6844	0.7684	0.4805
Use of diuretics %	49.7	53.9	47.3	43.6	45.2	41.7	0.1767	0.2373	0.3363
Use of anticoagulants %	11.9	11.5	12.1	7.4	7.8	7.0	0.0690	0.3471	0.1065
Use of anti-hypertensives %	72.0	76.9	69.2	68.1	67.6	68.7	0.3478	0.1700	0.9148
Use of ≥5 prescribed drugs %	37.8	36.5	38.5	30.5	31.3	29.5	0.0828	0.4414	0.0983
Nutrition score	36.6 (6.0)	38.3 (6.2)	35.7 (5.7)	38.6 (5.1)	39.1 (4.9)	38.0 (5.3)	<.0001	0.2502	0.0006
Increased alcohol intake %*	22.4	25.0	20.9	28.3	30.8	25.4	0.1443	0.3873	0.3684
PASE†	112.8 (53.5)	114.5 (57.4)	111.8 (51.5)	120.5 (55.5)	125.9 (60.7)	114.4 (48.3)	0.1150	0.1846	0.6584
BMI kg/m^2	27.7 (3.9)	27.6 (4.1)	27.7 (3.9)	28.6 (4.3)	28.6 (3.8)	28.6 (4.7)	0.0129	0.1021	0.1027

*alcohol intake >24 g/day in men and >12 g/day in women.
†Physical Activity Scale for the Elderly. Scores range from 0 to 361 [31].

results. However, we found an additive effect of anemia and disability on the occurrence of falls.

On the contrary to our study prior studies were mostly conducted in selected groups [15-17] in women only [32] or they used self-reported data regarding anemia status or information from chart reviews [33]. Furthermore, most of the former analyses were based on smaller study samples [15,17,18].

The group of Duh et al. employed a retrospective open-cohort design and analyzed data of 47,350 individuals regarding anemia and risk of injurious falls in community-dwelling elderly people. Results showed that anemia increased the risk of injurious falls by 1.47 times in multivariate analysis adjusting for age, gender, health plan, history of falls, co-morbidities, and concomitant medications [16]. A 50% higher risk of fall injuries in community-dwelling adults aged 65 and older was also reported by Herndon et al. [33]. However, contrary to the present study, in that case–control study (467 cases, 691 controls), anemia based on self-report was used. Both studies mentioned above concentrated on injurious falls whereas our database includes also falls which did not cause injuries.

Pandya et al. found even more than twice the risk of falling for anemic participants when retrospectively analyzing the relationship between anemia and falls in 564 nursing home residents. However, in that study, only a selection of relevant covariables was available and collected by chart review [15]. Dharmarajan et al. investigated in a case–control study the relationship between the presence of anemia and falls during hospitalization in 362 ambulatory adults aged 59–104 years from long-term care and community settings. They found a 22% decreased risk of falls for every 1.0 g/dL increase in Hb-concentration and a 1.9 times increased risk of falls in anemic hospitalized patients [17].

In another study, Lawlor et al. analyzed data of 4,050 female participants of the population-based British Women's Heart and Health Study aged 60 to 79 and found that women reporting at least one fall per year had lower mean Hb-concentrations than women who did not report a fall; the inverse association remained even after adjustment for social class, BMI, chronic diseases, and each class of drug used (OR of any falls for a 1 SD increase of Hb was 0.90, 95% CI 0.81-0.99) [32]. In contrast to these findings we could not find significantly lower Hb-concentrations for women who reported a fall. Additionally we found no significant relationship of Hb-concentrations and falls in women. Contrary to the other publications the observational study of Penninx et al. including 394 community-dwelling older persons from The Netherlands could not prove that anemia directly affects risk of falls although longitudinal data were used and disease and functioning status were adjusted for.

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Table 4 Results of logistic regression models

	Unadjusted model	Model 1	Model 2	Model 3
Hemoglobin-level (continuous, per SD decrease)				
Total sample	**1.36 (1.14-1.64)**	1.13 (0.92-1.38)	1.11 (0.90-1.37)	1.09 (0.89-1.34)
Age 65-74	1.25 (0.91-1.73)	1.12 (0.78-1.61)	1.09 (0.75-1.57)	1.10 (0.76-1.59)
Age >74	**1.35 (1.09-1.69)**	1.23 (0.97-1.57)	1.21 (0.94-1.55)	1.15 (0.89-1.48)
Men	1.25 (0.94-1.65)	1.15 (0.87-1.54)	1.14 (0.85-1.55)	1.11 (0.83-1.49)
Age 65-74	0.98 (0.60-1.62)		1.00 (0.60-1.66)	1.00 (0.60-1.66)
Age >74	1.33 (0.94-1.87)		1.29 (0.89-1.85)	1.19 (0.83-1.73)
Women	1.25 (0.95-1.64)	1.11 (0.83-1.47)	1.09 (0.81-1.45)	1.07 (0.80-1.43)
Age 65-74	1.28 (0.77-2.13)		1.21 (0.72-2.03)	1.22 (0.72-2.06)
Age >74	1.15 (0.83-1.61)		1.14 (0.81-1.60)	1.09 (0.76-1.54)
Anemia definition according WHO [12]				
Total sample	1.35 (0.87-2.09)	1.18 (0.75-1.86)	1.13 (0.71-1.80)	1.06 (0.66-1.70)
Age 65-74	1.24 (0.50-3.12)	1.23 (0.49-3.09)	1.17 (0.46-2.97)	1.21 (0.47-3.09)
Age >74	1.24 (0.74-2.05)	1.35 (0.81-2.26)	1.29 (0.76-2.19)	1.12 (0.65-1.92)
Men	1.79 (0.94-3.41)	1.51 (0.78-2.95)	1.49 (0.75-2.97)	1.35 (0.67-2.71)
Age 65-74	1.13 (0.24-5.30)		1.18 (0.25-5.61)	1.18 (0.24-5.90)
Age >74	1.85 (0.88-3.91)		1.73 (0.79-3.78)	1.50 (0.68-3.32)
Women	1.18 (0.65-2.17)	0.96 (0.52-1.80)	0.92 (0.49-1.74)	0.87 (0.46-1.66)
Age 65-74	1.29 (0.41-4.09)		1.20 (0.37-3.85)	1.22 (0.38-3.94)
Age >74	1.03 (0.50-2.11)		1.00 (0.48-2.08)	0.86 (0.40-1.81)
Joint analyses (total sample)				
Anemic & frail	**1.82 (1.05-3.15)**	1.32 (0.74-2.38)	1.27 (0.70-2.30)	
Anemic & not frail	1.51 (0.73-3.14)	1.54 (0.73-3.25)	1.49 (0.70-3.16)	
Not anemic & frail	**1.76 (1.17-2.63)**	1.40 (0.91-2.15)	1.38 (0.90-2.13)	
Not anemic & not frail	1.00	1.00	1.00	
Anemic & disabled	**2.99 (1.69-5.29)**	**2.17 (1.18-3.99)**	**2.10 (1.12-3.93)**	
Anemic & not disabled	0.94 (0.48-1.84)	0.87 (0.44-1.72)	0.85 (0.43-1.70)	
Not anemic & disabled	**2.32 (1.50-3.58)**	**1.64 (1.03-2.61)**	**1.61 (1.00-2.58)**	
Not anemic & not disabled	1.00	1.00	1.00	

Model 1: adjusted for age (in years, only in the whole sample and in sex-stratified analyses) and sex (only in the whole sample and in the age-stratified analyses).
Model 2: in addition to model 1 adjusted for number of drugs.
Model 3: in addition to model 2 adjusted for disability.
Significant results are written in bold.

The authors hypothesized that anemia could still be only a manifestation of disease severity which would be the true link between anemia and falls [18].

So far, no data are available showing the joint association of anemia and disability with the occurrence of falls in the elderly general population. The results of our study extend the understanding that different factors in elderly people can have an additive effect on the occurrence of falls. Although no independent association between anemia and falls was found in the present sample, it could be shown, that persons with disability and concomitant present anemia represent a high risk group for falls. The findings from the present data therefore suggest that in elderly, mainly multimorbid persons single risk factors should not be considered isolated in relation to certain outcomes, but rather in the context of other relevant disorders and restrictions.

We recognize that our study has limitations. First, participants were asked for falls which happened in the past year on the day the blood sample was taken. Therefore, the anemia status of a participant could have been different at the time when the fall occurred. However, it could be assumed that in the present sample almost all persons with anemia suffered from chronic and not from acute anemia and thus were well adapted to the low hemoglobin levels. Hence, it is most likely that the status of anemia was similar at both points of time. Second, the interview-based assessment of falls could be imprecise, as the interrogated person could have forgotten these events (consistency bias), or did not want to report them in order to not appear frail. We did not find an investigation on the reliability and validity of the NHANES questionnaire [20] used to assess falls, but the short and easy way to ask people about their history of falls indicates reliable results. Third, the exclusion of participants who could not come to the study center because of severe illnesses could have influenced the results as they would most likely have lower hemoglobin levels. This could possibly have led to an underestimation of the true association between anemia and falls. On the other hand it was necessary to exclude people who could not walk anymore as they would not experience falls. Fourth, the cross-sectional design of the study represents a limitation, implicating that cause and effect relationships cannot be discerned. Fifth we included the intermediary variable disability as confounder in the logistic regression model which could result in a decreased association between anemia and falls. But as the results of the logistic regression models were already not significant before including these variable, this should not have influenced our results.

Finally, another issue worth considering would be the number of falls, as it was analyzed by Penninx et al., who found a 1.91 times greater risk of recurrent falls in elderly people with anemia (n = 394) [18]. But in our study group only 92 participants fell once, and 51 fell more than once. When looking at the anemic participants only 22 people fell once and only 9 fell more than once. We considered these groups as too small for meaningful analyses. The strength of the study is the inclusion of a relative large number of individuals randomly drawn from the general population, and the availability of data on lifestyle, medication, and multiple metabolic risk factors.

Conclusion

In this analysis an independent relationship of anemia and falls in older people from the general population could not be demonstrated. The relationship shown in other studies including hospitalized or nursing home living participants or focusing on injurious falls could not be confirmed by our study population. Because there was an additive effect of anemia and disability on the occurrence of falls, blood count should be measured in disabled older men and women to identify persons, who are at particular high risk for falls. Further studies, in particular prospective studies need to be carried out to clarify the role of anemia regarding the occurrence of falls in elderly people from the general population.

Competing interests

The authors report no potential conflicts of interest.

Authors' contributions

KTK did the statistical analysis, generated all tables and drafted the manuscript. All calculations were checked and recalculated by CM to guarantee correctness. AD, AH and CM gave major suggestion on how to analyze and how to interpret the data and on the manuscript draft. All authors contributed to the design of the study and data collection. They also reviewed and edited the manuscript. All authors approved the final version of the manuscript.

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6 Publikation 2: Description of spatio-temporal gait parameters in elderly people and their association with history of falls: results of the population-based cross-sectional KORA-Age study

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RESEARCH ARTICLE Open Access

Description of spatio-temporal gait parameters in elderly people and their association with history of falls: results of the population-based cross-sectional KORA-Age study

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Abstract

Background: In this epidemiological study we described the characteristics of spatio-temporal gait parameters among a representative, population-based sample of 890 community-dwelling people aged 65 to 90 years. In addition, we investigated the associations between certain gait parameters and a history of falls in study participants.

Methods: In descriptive analyses spatio-temporal gait parameters were assessed according to history of falls, frailty, multimorbidity, gender, multiple medication use, disability status, and age group. Logistic regression models were calculated to examine the association between gait velocity and stride length with a history of falls (at least one fall in the last 12 month). Data on gait were collected on an electronic walkway on which participants walked at their usual pace.

Results: We found significant differences within gait parameters when stratifying by frailty, multimorbidity, disability and multiple medication use as well as age (cut point 75 years) and sex, with $p < 0.05$ for all gait parameters (velocity, cadence, time, stride duration, stride length, step width). After stratification by history of falls, only stride length showed a significant difference ($p < 0.05$) between the groups of fallers and non-fallers. Logistic regression models showed that a decreased stride length was independently associated with falls in men aged older than 74 years (OR 1.34 (CI: 1.05-1.70 per 10 cm decrease)), while this was neither the case for women of similar age nor for men or women aged 65 to 74 years. A decreased walking speed was not associated with falls.

Conclusion: Age, frailty, multimorbidity, disability, history of falls, sex, and multiple medication use show an association with different gait parameters measured during gait assessment on an electronic walkway in elderly people. Furthermore, stride length is a good indicator to differentiate fallers from non-fallers in older men from the general population.

Keywords: Gait parameters, Falls, Electronic walkway, Velocity, Fall risk

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Background

Humans need most of their early childhood to learn how to walk. In adulthood, walking is done almost automatically, but older adults again need to put more attention on the complex task of walking – if not, they are at risk of falling which is likely followed by serious injuries [1]. As a consequence, every third person aged 65 and older falls at least once per year [1,2]. In community-dwelling persons, a fall increases the risk of being sent to a nursing home by threefold [3] and every second fall leads to death within one year [4]. An impaired gait is one of the most prevalent and sensitive risk factors for falls. The majority of falls occur during some form of locomotion [1,3,5], especially when the person walks in an unknown environment or while performing another task e.g. speaking (dual-task walking). Therefore, gait evaluation is recommended in current fall guidelines. Several studies have shown that changes in certain spatial and temporal gait parameters such as velocity or step length increase fall risk [2,6-8]. Such changes in gait parameters are often very small and could not be identified without a device; therefore in the last few years instrumented gait analysis has become an important method used for fall risk detection, among others, electronic walkway mats are used [1]. These devices also overcome problems of other gait assessment instruments which are often subjective and examiner-dependent [9].

The prevalence of an abnormal gait is 35% in community-dwelling people aged 70 and older [10] although it is difficult to determine precisely what an abnormal gait is in an older adults [11]. Compared to young people, older people walk more slowly with a decreased stride length and with an increased stance width [12,13] and changes in gait in elderly people are often caused by underlying medical conditions [14,15]. Salzman gives a detailed overview of known medical conditions and risk factors associated with gait and balance disorders [16] and suggests to assess a patients' medical history including acute and chronic medical problems, history of falls, walking problems and usual physical activity when searching for fall risks.

Although there are a number of previous studies available that examine the association between gait parameters and history of falls [2,6,7,17-21], sex-specific analysis on this issue are scarce, so far only Paterson [18] focused exclusively on women. Furthermore, the study populations of prior investigations have been small. Except for Verghese [17] and Yamada [19], prior studies included less than 100 participants. In addition, large population-based studies examining the association between certain age-related impairments such as frailty, disability, use of multiple medications or multimorbidity and gait parameters are lacking. There are only a few publications describing gait parameters in the context of frailty [22,23] or use of multiple medications [24-26], but none that describe spatio-temporal gait parameters for other characteristics such as multimorbidity or disability.

In this study, we therefore aimed to comprehensively describe spatio-temporal gait parameters in a large sample of 890 community-dwelling adults aged 65 to 90 years drawn from the general population stratified by age groups, sex, history of falls, multimorbidity, frailty, multiple medications and disability status. Furthermore, we assessed the sex-specific associations between several spatio-temporal gait parameters measured with an electronic walkway and history of falls. Gait parameters were measured during a study participant's self-selected, normal pace.

Methods

Study design and participants

Data were collected during the cross-sectional KORA (Cooperative Health Research in the Region of Augsburg)-Age study which was conducted in 2009 as a follow-up study of the four MONICA/KORA Augsburg Surveys [27]. Out of a population based random sample (n = 5,991), 4,127 people aged 65 to 90 participated in a standardized telephone interview. A randomly drawn sample of 1,079 participants additionally underwent extensive physical examinations. Out of these participants, 118 did not complete the quantitative gait assessment and another 31 participants had to be excluded because of missing data for any of the considered variables. Additionally, 40 participants were excluded because they used a walking aid [28]. Thus, the final data set for the present analysis consisted of 890 participants (429 women and 461 men) aged 65–90 years. The study was approved by the ethics committee of the "Bayerische Landesärztekammer" and all participants provided written informed consent.

Data collection

Information on socio-demographic characteristics and lifestyle behavior was collected during a personal interview. To assess the history of falls, questions from the NHANES-questionnaire (National Health and Nutrition Examination Survey [29]) were used. The answers to the question "Did you fall in the previous year?" with possible answers "yes, once", "yes, more than once" and "no" were dichotomized in "at least one fall" and "no falls".

Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared, where weight and height were measured by trained medical staff. Participants were classified as frail when they met at least one of the criteria mentioned by Fried et al. [30-32]. Multimorbidity status was obtained via the criteria of Kirchberger et al. [33] and persons were defined as multimorbid when they suffered from two or more diseases.

Participants were divided into two groups according to their disability score (Stanford Health Assessment

Questionnaire [34]): persons were considered as disabled with a score of ≥0.5 and not disabled with a score of <0.5 as suggested in literature [35].

Drug intake during the week before the examination was recorded with the IDOM-Software [36] and then dichotomized in "5 or more different medications taken" and "less than 5 medications taken" since use of 5 and more medications has been shown to increase the risk to fall significantly [37-39].

Gait parameters

Quantitative gait assessment was performed by using a 488 × 61 cm electronic walkway mat with embedded pressure sensors (GAITRite; CIR Systems, Haverton, Pa., USA). Participants were asked to walk over the walkway at their normal (usual) pace. Start and stop points were marked on the floor [40] and participants were asked to take some strides before striking the mat and to continue their walk after the end of the mat to avoid slowing down on the mat. Before the actual measurement, everyone was allowed a trial. Based on the recorded footfalls, the walkway calculates several different gait variables which are described in detail by the manufacturer [41].

We did not to use variables describing gait variability such as step length variability, calculated as standard deviation during one walk, because we did not have enough steps measured at one speed to make significant conclusions [42,43]. The GAITRite system calculates each variable separately for left and right steps and also once including left and right steps (limb-independent variable).

Statistical analyses

Characteristics of the study population were calculated as means and standard deviation for continuous variables and absolute number and percentages for categorical variables for the whole study sample and also stratified by sex.

Additionally we calculated means and standard deviation for the continuous gait variables velocity, cadence, time, duration, stride length, and step width stratified by history of falls, frailty, multimorbidity and disability status, as well as multiple medications, sex and age groups. All selected continuous gait variables were normally distributed. The Chi^2-test was used to test the differences in prevalence. The t-test was used to compare means. As a result of the descriptive analysis (p-value < 0.05 for difference between fallers and non-fallers), we decided to analyze the association between stride length (10 cm-decrease) and history of falls using logistic regression models. We also analyzed the association between velocity (10 cm/s-decrease) and history of falls because it is widely used and topic of many publications.

We considered a variable as confounder in the regression models if it was significantly related to falls as well as to the gait parameter or if literature suggested including the variable as confounder. BMI was used to assess the influence of height and weight on the results.

All logistic regression models were stratified by sex and age (2 groups: 65 to 74 and older than 74 years). We calculated 3 models: the unadjusted model included the respective gait parameter only, model 1 included in addition BMI, disability, and frailty status as confounders and model 2 which additionally to model 1 included elevated drug intake and multimorbidity as confounders. Results of the models were presented as Odds Ratios (ORs) and corresponding 95% confidence intervals (CIs). P-values ≤0.05 were considered as statistically significant. All analyses were performed with SAS (version 9.2, SAS Institute Inc, Cary, NC, USA).

Results

Study sample characteristics

A description of the study population can be found in Table 1. The mean age of the study participants was 75.4 years (SD ± 6.3 years).Women fell more often than men (16.6% vs. 10.4% falls in the last year, $c^2(1) = 7.23$, $p = 0.0072$) and reported almost twice as many recurrent falls than men ($c^2(2) = 7.92$, $p = 0.0191$). Another significant sex difference could be found for disability status: 27.9% of women and 15.4% of men were classified as disabled ($c^2(1) = 11.6$, $p = 0.0007$). Regarding frailty, multimorbidity, BMI, and elevated drug intake, no significant differences between men and women could be found. Mean height and weight were significantly different between men and women (t(15.25) and t(29.89), p < .0001).

Gait parameter characteristics

In Table 2 spatio-temporal gait parameters stratified by history of falls, frailty, multimorbidity, multiple medications and disability status as well as age groups and sex are shown. Gait parameters for participants who reported one or more falls in the last year (fallers) as well as participants who did not report a fall in the last year (non-fallers) differed significantly only for stride length (t(−2.59), p = 0.0106) and normed stride length (t(−2.80), p = 0.0052).

All examined spatio-temporal gait parameters differed significantly between frail and non-frail people. Frail people walked slower, with fewer steps per minute and had shorter steps. Also the step width showed a significant difference: frail people needed a wider walk to keep their balance.

The same patterns were found for multimorbid compared to not multimorbid participants, and disabled compared to not disabled people. Participants using 5 and more different medications compared to persons

Table 1 Study sample characteristics by gender (n (percentages) or means (±SD)

Variable	Males (n = 461)	Females (n = 429)	All (n = 890)	t-value, c^2-value, and P Value (t-test/ Chi-square test)
Mean age, y	75.5 (6.3)	75.3 (6.2)	75.4 (6.3)	t(0.59), p = 0.5582
Falls, n (%)	48 (10.4%)	71 (16.6%)	119 (13.4%)	$c^2(1) = 7.23$, p = 0.0072
Recurrent falls, n (%)	14 (3.0%)	26 (6.1%)	40 (4.5%)	$c^2(2) = 7.92$, p = 0.0191
Multimorbidity*, n (%)	283 (61.4%)	278 (64.8%)	561 (63.0%)	$c^2(1) = 1.11$, p = 0.2918
Disability+, n (%)	70 (15.2%)	104 (24.2%)	174 (19.6%)	$c^2(1) = 11.6$, p = 0.0007
Frailty**, n (%)	176 (38.2%)	154 (35.9%)	330 (37.1%)	$c^2(1) = 0.50$, p = 0.4816
Use of ≥ 5 prescribed drugs++, n (%)	146 (31.7%)	125 (29.1%)	271 (30.5%)	$c^2(1) = 0.67$, p = 0.4120
Mean BMI, kg/m^2	28.3 (3.6)	28.2 (4.5)	28.2 (4.1)	t(0.12), p = 0.9061
Mean weight, kg	82.7 (12.1)	70.5 (11.9)	76.8 (13.5)	t(15.25), p < .0001
Mean height, cm	171 (6.8)	158 (6.2)	164.7 (9.2)	t(29.89), p < .0001

*According to criteria of Kirchberger et al. [33].
+According to Stanford Health Assessment Questionnaire [34], threshold 0.5 [35].
**Includes pre-frail and frail persons which fulfill at least one criteria of Fried et al. [30-32].
++recorded with IDOM-Software [36].

taking less than 5 medications and persons aged 75 years and older compared to the age group 65 to 74 years also showed a decreased stride length, velocity, and cadence and an increased step width. Women showed significantly lower values for the parameters velocity, stride length, step with and higher values for cadence and stride duration than men.

Logistic regression analysis

A positive association between velocity and history of falls was found in the unadjusted models for the age-group >74 years (OR per 10 cm/s decrease 1.14 (95% CI 1.02-1.28) and for older men (OR 1.20 95% CI 1.01-1.43). Further adjustment for relevant confounding variables attenuated the associations, which became non-significant (Table 3).

Regarding stride length, there was also no significant association with history of falls in men or women aged 65–74 years. In the age-group 75 years and older, stride length (per 10 cm decrease) showed a significant relationship to falls in all models in men only (OR 1.34; 95% CI 1.05-1.70; model 2) (Table 3).

As a sensitivity analysis, we adjusted for height and weight instead of BMI in the logistic regression models. However, the results remained quite the same.

Discussion

The present study includes a large population-representative sample of men and women aged 65 to 90 years and provides a comprehensive overview regarding differences in gait parameters among different subgroups. We could show that increased age, frailty, multimorbidity, disability, sex, and the use of multiple medications have an influence on a person's gait, probably/which more likely leads to immobility and falls. We also found that a decreased stride length is significantly associated with falls in men aged older than 74 years and that a decreased walking speed was not related to the history of falls in both elderly men and women from the general population.

Description of gait parameters

The prevalence of gait disorders increases with age; e.g. Verghese found a prevalence of 25% for persons 70 to 74 years old and nearly 60% for persons aged 80 to 84 [10]. This was confirmed by our results, because we found that persons aged 75 years and older walked significantly slower with shorter steps and with an increased step width in comparison to the age-group 65 to 74 years. This result may represent an adaption to changes in sensory or motor system to make walking safer with increasing age [16]. In the present study we also could identify sex-differences regarding gait parameters: elderly women showed significantly lower values for the parameters velocity, stride length, step with and higher values for cadence and stride duration than elderly men. A finding which suggests that there may be sex-specific changes in gait in older adults from the general population. Literature suggests that using 3 or more medications [24,25], or 5 and more medications [37], leads to gait disorders and an increased fall risk. In our study, the group of persons taking 5 or more medications walked slower, with shorter steps and an increased step width ($p < 0.05$ for all parameters) in comparison to persons taking less than 5 medications, confirming the established observation.

In multimorbid and disabled persons we also saw a slower walk, shorter steps and an increased step width. These results demonstrate the large influence of multimorbidity and frailty on the gait of a person which could

Table 2 Gait parameters stratified by history of fall, frailty, multimorbidity, multiple medications and disability status as well as age groups and gender

Characteristics	Velocity (cm/s)	Cadence (steps/min)	Time (s)	Stride duration* (s)	Stride length (cm)	Normed stride length	Step width (cm)	Normed step width
Fall participants (n = 119)	105.5 (24.7)	106.3 (12.2)	4.12 (1.29)	1.14 (0.15)	**118.9 (20.4)**	**1.34 (0.23)**	8.79 (3.25)	0.10 (0.04)
Non-fall participants (n = 771)	108.9 (22.9)	105.4 (13.1)	3.89 (1.14)	1.14 (0.16)	**124.0 (18.1)**	**1.40 (0.19)**	8.73 (3.22)	0.10 (0.04)
t- and p-value	t(−1.43), p = 0.1550	t(0.77), p = 0.4437	t(1.83), p = 0.0686	t(−0.65), p = 0.5170	**t(−2.59), p = 0.0106**	**t(−2.80), p = 0.0052**	t(0.18), p = 0.8541	t(0.21), p = 0.8310
Frail participants (n = 330)	**95.5 (21.2)**	**101.9 (13.2)**	**4.53 (1.34)**	**1.19 (0.18)**	**112.5 (17.5)**	**1.28 (0.19)**	**9.58 (3.31)**	**0.09 (0.03)**
Non-frail participants (n = 560)	**116.2 (20.7)**	**107.7 (12.4)**	**3.56 (0.87)**	**1.13 (0.15)**	**129.8 (15.9)**	**1.46 (0.16)**	**8.24 (3.06)**	**0.11 (0.04)**
t- and p-value	**t(14.16), p = <.0001**	**t(6.46), p = <.0001**	**t(−13.09), p = <.0001**	**t(−6.13), p = <.0001**	**t(14.74), p = <.0001**	**t(−6.01), p = <.0001**	**t(14.83), p = <.0001**	**t(−6.46), p = <.0001**
Multimorbid participants (n = 561)	**104.4 (22.5)**	**104.6 (12.6)**	**4.09 (1.22)**	**1.16 (0.16)**	**119.7 (18.6)**	**1.46 (0.18)**	**9.06 (3.22)**	**0.09 (0.04)**
Not multimorbid participants (n = 329)	**115.5 (22.6)**	**107.2 (13.4)**	**3.62 (0.99)**	**1.13 (0.17)**	**129.5 (16.6)**	**1.35 (0.19)**	**8.20 (3.15)**	**0.10 (0.04)**
t- and p-value	**t(7.12), p = <.0001**	**t(2.84), p = 0.0046**	**t(−5.96), p = <.0001**	**t(−2.30), p = 0.0220**	**t(7.86), p = <.0001**	**t(−3.88), p = 0.0001**	**t(8.24), p = <.0001**	**t(−4.15), p = <.0001**
Disabled participants (n = 174)	**91.5 (19.9)**	**101.3 (11.9)**	**4.76 (1.39)**	**1.20 (0.17)**	**108.6 (18.1)**	**1.43 (0.18)**	**9.68 (3.31)**	**0.10 (0.04)**
Non-disabled participants (n = 716)	**112.6 (22.0)**	**106.6 (13.0)**	**3.71 (1.00)**	**1.14 (0.16)**	**126.9 (16.8)**	**1.33 (0.19)**	**8.51 (3.16)**	**0.11 (0.04)**
t- and p-value	**t(12.31), p = <.0001**	**t(5.13), p = <.0001**	**t(−11.45), p = <.0001**	**t(−4.18), p = <.0001**	**t(12.17), p = <.0001**	**t(−4.22), p = <.0001**	**t(12.19), p = <.0001**	**t(−4.56), p = <.0001**
Participants taking 5 and more drugs (n = 271)	**101.3 (23.2)**	**103.3 (13.9)**	**4.26 (1.34)**	**1.18 (0.18)**	**117.5 (18.7)**	**1.42 (0.19)**	**9.38 (3.48)**	**0.10 (0.03)**
Participants taking less than 5 drugs (n = 619)	**111.6 (22.5)**	**106.5 (12.4)**	**3.77 (1.05)**	**1.14 (0.15)**	**125.9 (17.8)**	**1.32 (0.20)**	**8.46 (3.06)**	**0.11 (0.04)**
t- and p-value	**t(6.19), p = <.0001**	**t(3.37), p = 0.0008**	**t(−5.93), p = <.0001**	**t(−3.12), p = 0.0018**	**t(6.22), p = <.0001**	**t(−3.94), p = <.0001**	**t(6.75), p = <.0001**	**t(−3.99), p = <.0001**
"Young old" (age < 75, n = 410)	**117.9 (21.5)**	**108.4 (11.8)**	**3.52 (0.91)**	**1.12 (0.13)**	**130.5 (16.6)**	**1.47 (0.18)**	**8.26 (3.10)**	**0.09 (0.03)**
"Old Old" (age > = 75, n = 480)	**100.5 (21.5)**	**103.0 (13.4)**	**4.36 (1.25)**	**1.18 (0.18)**	**117.2 (17.8)**	**1.32 (0.18)**	**9.15 (3.26)**	**0.10 (0.04)**
t- and p-value	**t(12.03), p = <.0001**	**t(6.31), p = <.0001**	**t(−9.99), p = <.0001**	**t(−6.28), p = <.0001**	**t(11.5), p = <.0001**	**t(−4.17), p = <.0001**	**t(11.81), p = <.0001**	**t(−4.54), p = <.0001**
Men (n = 461)	**110.1 (23.0)**	**102.6 (11.7)**	**3.82 (1.13)**	**1.18 (1.17)**	**128.7 (19.1)**	**1.42 (0.20)**	**9.45 (3.43)**	**0.10 (0.04)**
Women (n = 429)	**106.8 (23.2)**	**108.7 (13.5)**	**4.02 (1.20)**	**1.12 (1.10)**	**117.6 (15.9)**	**1.36 (0.18)**	**8.05 (2.94)**	**0.09 (0.03)**
t- and p-value	**t(2.12), p = 0.0344**	**t(−7.14), p = <.0001**	**t(−2.6), p = 0.0094**	**t(5.99), p = <.0001**	**t(9.36), p = <.0001**	**t(6.54), p = <.0001**	**t(3.89), p = 0.0001**	**t(4.44), p = <.0001**

*A stride begins with the foot contact and ends with the subsequent foot contact of one foot.
Significant differences are written bold.

Table 3 Age- and gender-stratified results of logistic regression models for the association between velocity and stride length and history of falls

Velocity (10 cm/s decrease)	Unadjusted model	Model 1	Model 2
Age 65 to 74 years	0.91 (0.78-1.05)	0.91 (0.77-1.08)	0.89 (0.75-1.06)
Men	0.97 (0.76-1.24)	1.06 (0.81-1.38)	1.06 (0.81-1.39)
Women	0.86 (0.72-1.04)	0.83 (0.67-1.03)	0.80 (0.64-1.00)
Age >74 years	**1.14 (1.02-1.28)**	1.10 (0.96-1.26)	1.09 (0.95-1.26)
Men	**1.20 (1.01-1.43)**	1.18 (0.97-1.43)	1.16 (0.96-1.42)
Women	1.07 (0.91-1.26)	1.00 (0.82-1.22)	1.00 (0.82-1.23)
Stride length (10 cm decrease)	**Unadjusted model**	**Model 1**	**Model 2**
Age 65 to 74 years	0.93 (0.77-1.12)	0.94 (0.77-1.16)	0.92 (0.75-1.14)
Men	0.87 (0.64-1.19)	0.94 (0.67-1.33)	0.93 (0.65-1.33)
Women	0.82 (0.61-1.10)	0.77 (0.55-1.07)	0.70 (0.50-1.00)
Age >74 years	**1.30 (1.12-1.50)**	**1.27 (1.07-1.51)**	**1.25 (1.04-1.49)**
Men	**1.33 (1.09-1.63)**	**1.36 (1.07-1.72)**	**1.34 (1.05-1.70)**
Women	1.18 (0.93-1.50)	1.10 (0.83-1.47)	1.08 (0.81-1.45)

Model 1: adjusted for BMI, disability, frailty.
Model 2: in addition to model 1 adjusted for more than 5 drugs used and multimorbidity.
Significant results are written bold.

then lead to falls, an observation which is in agreement with the work of Salzman [16], who summarized this in his article about medical conditions and risk factors for gait disorders.

In two prior publications, the association between gait parameters and frailty was examined, using the same criteria of Fried et al. [30] to classify frailty as in our study. Just recently Guedes et al. reported that gait speed could separate frail from pre- and non-frail persons [23] and showed a decreased stride length (0.96 ± 0.16 vs. 1.35 ± 0.09 m) as well as a decreased cadence (105.36 ± 13.39 vs. 114.90 ± 6.40 steps/min) for frail persons. Schoon et al. came to similar results in their publication including 593 community-dwelling subjects 70 years and older: gait speed was highly correlated with frailty and had a high diagnostic value [22].

Association of gait parameters and falls

Gait speed is a widely used measure in geriatric assessment [44] because it can be measured easily and quickly. In a prior cross-sectional study it was shown that gait speed influences gait variability in community-dwelling older adults aged 65 and older (mean 79.4 ± 3.37) [45] and in a longitudinal study a decreased walking speed predicted falls in patients with dementia living in nursing homes [46]. One prior study including 597 community-dwelling participants aged 70 and older (mean 80.5 ± 5.4)), showed that a decrease in gait speed increases the risk of falls (OR 1.069). Contrary to our results regarding the association of gait parameters and falls, in that study it could be shown that the lower the speed the higher the OR (1.54 for speed less than 70 cm/s, 1.28 for speed between 70 and 100) [17]. An increased risk was also found for swing phase, double support phase, swing time variability and stride length variability with the strongest result for stride length variability. However, contrary to the present work, the analysis in that study was not stratified by sex and/or age and a longitudinal fall assessment was used, limiting the comparability of the results.

Another longitudinal analysis on gait parameters and fall risk including only community dwelling women [18] reported that inter limb differences in stride dynamics showed an association with history of falls, but that no gait variable predicted falls.

Already in 1997 investigations [6,47] found that stride-to-stride variability increases fall risk, a finding confirmed in another study which also showed that stride-to-stride fluctuations and stride and swing time variability increase fall risk [2]. In our study it was not possible to consider variables of gait variability in the analysis, because there were not enough measured steps available at one speed to draw significant conclusions [48].

Limitations

Our study certainly had limitations. First of all people were asked to recall any fall in the previous year which could bias the results, as people could have forgotten to report a fall or simply didn't want to report it to not appear frail. According to Ganz et al. [49] this question is relatively specific (91-95%), but less sensitive (80-89%). Furthermore, we recognize that capturing a greater number of steps would have strengthened the present results. The length of the walkway did not allow us to collect enough steps per person in order to analyze gait variability measures which would possibly have given additional information [6,17]. But with a mean of 6.8 (SD ±1.5) steps on the walkway mat, we collected enough steps to analyze velocity and stride length and their association with falls [43,50]. Other publications suggest that using a continuous walking protocol instead of short walks would improve reliability [51]. Nonetheless, this was impractical in this geriatric assessment and does not reflect daily life where multiple short distance walks are common [43]. The cross-sectional design of the study represents a further limitation for the analysis of association with falls, implicating that cause and effect relationships cannot be discerned. We cannot exclude that unknown risk factors may have biased or confounded the present analysis.

Another limitation is that it was not possible to use the dual-task data, which could have improved the results [21,48,52]. The walkway we used was too short and the complexity of our secondary task not high enough [53,54]. However, whether dual task tests for fall assessment should be performed still remains controversial [20,55-58]. The strength of the study is the inclusion of a large number of individuals randomly drawn from the general population and the availability of a number of characteristics of the participants.

Conclusion

The present work summarizes cross-sectional spatio-temporal gait data in a considerable sample of elderly men and women randomly drawn from the general population and therefore presents an important contribution to the existing literature on walking parameters in the elderly. Results indicate that age, sex, frailty, multimorbidity, disability and multiple medications have an influence on the gait of a person which may lead to immobility and falls.

Our results also confirm that stride length measured on an electronic walkway is strongly related to history of falls in older men from the general population. The results of the present study extend the present knowledge on gait parameters and falls to very old persons up to 90 years, and showed that there are sex-specific particularities regarding this issue which should be considered in fall prevention.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KTK did the statistical analysis, generated all tables and drafted the manuscript. All calculations were checked and recalculated by CM to guarantee correctness. CM gave major suggestion on how to analyze and how to interpret the data and on the manuscript draft. All authors contributed to the design of the study and data collection. They also reviewed and edited the manuscript. All authors approved the final version of the manuscript.

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