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Title: Economic impact of medication nonadherence by disease groups: a systematic review

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Abstract

Objective: To determine the economic impact of medication nonadherence across multiple disease groups.

Design: Systematic review.

Evidence Review: A comprehensive literature search was conducted in PubMed and Scopus in September 2017. Studies quantifying the cost of medication nonadherence in relation to economic impact were included. Relevant information was extracted and quality assessed using the Drummond checklist.

Results: Seventy nine individual studies assessing the cost of medication nonadherence across fourteen disease groups were included. Wide scoping cost variations were reported, with lower levels of adherence generally associated with higher total costs. The annual adjusted disease specific economic cost of nonadherence per person ranged from $949-$44,190 (in 2015 US dollars). Costs attributed to "all causes" nonadherence ranged from $5,271 to $52,341. Medication possession ratio was the metric most utilized to calculate patient adherence, with varying cut-off points defining nonadherence. The main indicators used to measure the cost of nonadherence were total cost or total healthcare cost (83% of studies), pharmacy costs (70%), inpatient costs (46%), outpatient costs (50%), emergency department visit costs (27%), medical costs (29%) and hospitalization costs (18%). Drummond quality assessment yielded 10 studies of high quality with all studies performing partial economic evaluations to varying extents.

Conclusion: Medication nonadherence places a significant cost burden on healthcare systems. Current research assessing the economic impact of medication nonadherence is limited and of varying quality, failing to provide adaptable data to influence health policy. The correlation between increased nonadherence and higher disease prevalence should be used to inform policy makers to help circumvent avoidable costs to the healthcare system. Differences in methods make the comparison amongst studies challenging and an accurate estimation of true magnitude of the cost impossible. Standardization of the metric measures used to estimate medication nonadherence and development of a streamlined approach to quantify costs is required.

Registration: CRD42015027338

Strengths and Limitations of this study:

- This is a novel attempt to use existing studies to broaden the scope of knowledge associated with the economic impact of medication nonadherence via quantifying the cost of medication nonadherence across different disease groups.
- A large comprehensive review – 2,768 citations identified, 79 studies included.
- Inability to perform a meaningful meta-analysis- insufficient statistical data and considerable heterogeneity according to outcome/indicators.
- Robust application of adapted Drummond checklist to evaluate the quality of economic evaluations.

1 Introduction

Nearly half of all adults and approximately 8% of children (aged 5-17 years) worldwide have a chronic condition[1]. This, together with ageing populations, is increasing the demand on healthcare resources[2]. Medications represent a cost-effective treatment modality[3], but with estimates of 50% nonadherence to long term therapy for chronic illnesses[4], intentional and unintentional medication nonadherence signifies a prevalent and persistent healthcare problem. Medication adherence is defined as 'the extent to which the patients' behavior matches agreed recommendations from the prescriber', emphasizing the importance on the patients' decisions and highlighting the modifiable aspect of nonadherence[5].

Given the proportion of the population who do not adhere to their medication efforts to improve medication adherence represent an opportunity to enhance health outcomes and health system efficiency. Annual costings of medication nonadherence range from US$100-$290 billion[6] in the United States, €1.25 billion[7] in Europe and approximately A$7 billion[8 9] in Australia. Additionally ten percent of hospitalizations in older adults are attributed to medication nonadherence [10 11] with the typical nonadherent patient requiring three extra medical visits per year leading to $2000 increased treatment costs per annum[12]. In diabetes the estimated costs savings associated with improving medication nonadherence range from $661 million to $1.16 billion [13]. Nonadherence is thus a critical clinical and economic problem[4].

Healthcare reformers and payers have repeatedly relied on cost effectiveness analysis to help healthcare systems deal with the rising costs of care[14]. However there is still a budgetary problem that needs to be considered, especially given the widespread policy debate over how to best bend the healthcare cost curve downward[15] and the proportion of healthcare budgets spent on prescription medication[16]. Quantifying the cost of medication nonadherence will help demonstrate the causal effect between medication nonadherence, increased disease prevalence and healthcare resource use. Justification of the associated financial benefit may incentivize health policy discussion about the value of medication adherence and promote the adoption of medication adherence intervention programs [15].

The objective of this systematic review was, first, to determine the economic impact of medication nonadherence across multiple disease groups, and second, to review and critically appraise the literature to identify the main methodological issues that may explain the differences among reports in the cost calculation and classification of nonadherence.

2 Methods

The protocol for this systematic review was registered on the PROSPERO: International prospective register of systematic reviews database (CRD42015027338) and can be accessed at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015027338. The systematic review was undertaken in accordance with PRISMA guidelines[17].

2.1 Search strategy and selection criteria

A literature search was conducted in September 2017. Studies reporting the cost of medication nonadherence for any disease state were included. Searches were conducted in PubMed and Scopus. Neither publication date nor language restriction filters were used. The search used in PubMed was: (non-adherence[TIAB]) OR ("Patient Compliance"[MH] AND ("Drug Therapy"[MH]) OR medication[TIAB])) OR "Medication adherence"[MH] AND (costs[TIAB] OR "Costs and Cost Analysis"[MH] OR burden[TIAB]). This was adapted for other databases (eTable 1). Duplicate records were removed.

To identify relevant articles, an initial title and abstract screening was conducted by the lead reviewer (RC) to identify studies appropriate to the study question. This process was over-inclusive. In the second phase appraisal, potentially relevant full text papers were read and excluded based on the following criteria: i) papers not reporting the cost of medication nonadherence as a monetary value, ii) systematic reviews, iii) papers not reporting a baseline cost of medication nonadherence prior to the provision of an intervention and iv) papers not reporting original data. Any uncertainty was discussed amongst two adherence experts (RC and VGC) and resolved via consensus.

2.2 Extracted information

A data extraction form was developed based on the Cochrane Handbook for systematic reviews[18] and piloted on a sample of included studies. The extracted information included the source (study identification, citation and title), eligibility (confirmation of inclusion criteria), objective, methods (study design, study groups, year data extracted, follow up period, comparison, adherence measure, adherence data source and adherence definition), population (sample size, setting, country, disease state/drug studied, inclusion/exclusion criteria and perspective), impact/outcome indicators (indicators measured, indicator data source, indicator definitions and characteristics of the method of assessment), results (costs reported, standardized costs, type of costs, non-cost findings, sub-

group analysis and statistical significance), conclusions and miscellaneous (funding source, references to other relevant studies, limitations and reviewers comments).

Costs were defined as any indicator associated with medication nonadherence that was quantified with a monetary value in the original study. This included direct costs (those costs borne by the healthcare system, community and patients' families in addressing the illness), indirect costs (mainly productivity losses to society caused by the health problem or disease) and avoidable costs (those costs incurred for patients suffering complications, resulting from suboptimal medicines use, and patients with the same disease who experienced no complications). The indicators were grouped for analysis based on the original studies classification of the cost. All costs were converted to US dollars (2015 values) using the Cochrane Economics Methods Group - Evidence for Policy and Practice Information and Coordinating -Centre Cost Converter tool [19], allowing meaningful comparisons between nonadherence cost data. This online tool uses a two stage computation process to adjust estimates of costs for currency and/or price year utilizing a Gross Domestic Product deflator index and Purchasing Power Parities for Gross Domestic Product[19]. The PPP values given by the International Monetary Fund were chosen. If details of the original price year could not be ascertained from a study the mid-point year of the study period was used for calculations. The mean cost was calculated and reported where studies separated out costs for different confounding factors within the one outcome measure in a disease state. Annual costs were extrapolated from the original study data if results were not presented in this manner.

The definition of medication nonadherence was derived from the included studies; with nonadherence referring to differing degrees of adherence based on the studies metric of estimation. Multiple nonadherence costs from individual studies may have been included where further sub-classification of nonadherence levels was defined. The analysis assessed nonadherence costs within disease groups, with disease group and cost classification derived from the study. Total healthcare costs included direct costs to the healthcare system while total costs incorporated direct and indirect costs.

2.3 Quality criteria and economic evaluation classification

Economic evaluation requires a comparison of two or more alternative courses of action, while considering both the inputs and outputs associated with each [20]. All studies were classified in accordance with Drummond's distinguishing characteristics of healthcare evaluations as either partial evaluations (outcome description, cost description, cost-outcome description, efficacy or

effectiveness evaluation, cost analysis) or full economic evaluations (cost benefit analysis, cost utility analysis, cost effectiveness analysis, cost minimization analysis) by team consensus (RC and VGC).

The Drummond checklist [21] for economic evaluation was used to assess the quality of studies. The original checklist was modified to remove inapplicable items (4, 5, 12, 14, 15, 30 and 31) as no full economic evaluation met all inclusion criteria. A score of 1 was assigned if the study included the required item and zero if it did not with a maximum potential score of 28. The study was classified as high quality if at least 75% of Drummond's criteria were satisfied, medium quality if 51-74% were satisfied and low quality if 50% of the criteria or less were satisfied.

2.4 Meta-Analysis

Outcome/indicator costs were independently extracted utilizing predesigned data extraction forms (total healthcare costs, total costs, inpatient costs, outpatient costs, pharmacy costs, medical costs, emergency department costs, and hospitalisation costs) for the purpose of integrating the findings on the cost of medication nonadherence to pool data and increase the power of analysis.

3 Results

3.1 Study Selection

Search strategies retrieved 2768 potential articles after duplicates were removed. Two hundred and eighty nine articles were selected for full text review. Seventy nine studies were included in the review (Figure 1). Numerous other papers do discuss nonadherence costs however addressed tangential issues or did not present primary relevant data. Many studies failed to report the monetary value of medication nonadherence associated with a range of cost estimate indicators.

3.2 Characteristics of individual studies

Sixty-six studies (83%) were conducted in the Unites States[10 22-86], four in Europe[87-90], four in Asia[91-94], three in Canada[95-97], one in the United Kingdom[98] and one across multiple countries throughout Europe and the United Kingdom[99]. Publication years ranged from 1997 to 2017; in accordance with the Cochrane Handbook for Systematic Reviews no date restriction filters were used[18] with earlier studies following the same pattern of association between medication nonadherence and increasing healthcare costs. Individual studies reported a large variety of costs, calculated by varying means. Forty-four studies (56%) reported unadjusted costs[22 26 27 30 32-36 38-43 46 48-50 52-56 58 63-68 72 75 81-83 86 88-90 92-94 99], 21 (26%) adjusted costs[10 23-25 29 31 44 51 57 59-61 71 73 76-78 84 85 87 91], 11 a combination of adjusted and unadjusted[28 37 45 47 62 69 70 74 79 80 97], two unadjusted and predicted[95 96] and one predicted costs[98]. The method of determining nonadherence ranged significantly between studies with majority of papers utilizing pharmacy and/or healthcare claims data (97%)[10 22-29 31-52 55 57 59-88 92-97]. Some studies utilized a combination of surveys or questionnaires, observational assessment, previous study data and disease state specific recommended guidelines. Medication possession ratio (MPR) was the most utilized method to calculate patient nonadherence with 51 studies (63%) reporting nonadherence based on this measure[24 25 28 29 32-36 40-44 46 47 49-51 55 57 58 60-64 67-78 81 82 86-88 92-97]; however, the cut-off points to define medication nonadherence differed with some studies classifying nonadherence as less than 80% medication possession and others through sub-classification of percentage ranges (e.g., 0-20%, 20-40%, 40-60%, 60-80%, 80-100%). The proportion of days covered (PDC) was the next most common measure of nonadherence (11%)[31 37 45 48 52 79 80 83-85], with all other studies utilizing an array of measures including self-report[98], urine testing[56], observational assessment[99], time to discontinuation[59], cumulative possession

ratio[23], disease specific medication management guidelines[66 89], Morisky 4-Item scale[53], medication gaps[38], prescription refill rates[22 27] and medication supplies[10]. The main characteristics of the included studies are summarized in eTable 2.

3.3 Quality assessment and classification of economic evaluations

The quality assessment of economic evaluations yielded 10 studies of high[33 37 40 50 51 57 71 75 87 93], 59 of medium[10 22-26 28-32 34-36 38 39 41-48 53-56 58 59 61-64 66 67 69 70 72 73 76-82 84-86 88 89 91 94-99] and ten of low quality[27 49 60 65 68 74 83 90 92]. Scores ranged from 26.1% to 87.5% (mean 62.63%). Only one study identified the form of economic evaluation used and justified it in relation to the questions that were being addressed [71]. The item 'the choice of discount rate is stated and justified' was applicable only to studies covering a time period of more than one year; all studies that cover more than one year failed to identify or explain why costs had not been discounted. Details of the analysis and interpretation of results were lacking in the majority of studies resulting in medium or low quality scores.

Through utilization of Drummond's distinguishing characteristics of healthcare evaluations criteria[20] it is apparent that no full economic evaluation was conducted in any of the included studies. All studies performed partial economic evaluations of varying extents. The classification of economic evaluations resulted in 59 cost description studies (74% of those included), 15 cost outcome descriptions and five cost analysis studies (eTable 2).

3.4 Medication nonadherence and costs

The cost analysis of studies (figure 2 and figure 3) reported annual medication nonadherence costs incurred by the patient per year. The adjusted total cost of nonadherence across all disease groups ranged from $949 to $52,341, while the unadjusted total cost ranged from $669 to $162,699. Figure 2 and figure 3 highlight the minimum, maximum and interquartile range of annual costs incurred by patients across disease groups where three or more studies were included for review. All cause costs encompass nonadherence costs incurred in mixed disease state studies, taking into account other confounding factors such as comorbidities.

Many different indicators were used to estimate medication nonadherence costs with no clear definition of what was incorporated in each cost component. The composition of included costs to estimate total cost or total healthcare cost varied significantly between studies thus indicators were

grouped for analysis based on the original studies classification of the cost. The main ones were total cost or total healthcare cost (83%), pharmacy costs (70%), outpatient costs (50%), inpatient costs (46%), medical costs (29%), emergency department costs (27%), and hospitalization costs (18%) (eTable 2). Avoidable costs (e.g., unnecessary hospitalizations, physician office visits and healthcare resource utilization) were not well defined with majority of studies failing to quantify these costs.

Lower levels of adherence across all measures (*e.g.,* MPR, PDC) were generally associated with higher total costs. From those that reported total or total healthcare costs, 39 studies (49%) reported nonadherence costs to be greater than adherence costs[24 25 27 29 31 32 34 37-39 42 43 47 49 50 55 56 58 61-65 70-78 84 86 87 96-99] and 11 studies (15%) reported nonadherence costs to be less than adherence costs[23 26 36 44 59 63 66 81 92 94 95]. Four reported fluctuating findings based on varying nonadherence cost subcategories[33 48 67 93] and two studies reported conflicting findings between adjusted and unadjusted costs [79 80]. Higher all cause total nonadherence costs and lower disease group specific nonadherence costs were reported in four studies[41 68 85 91], whereas Hansen et al[47] reported all cause total nonadherence costs to be lower ($18540 vs. $52302) but disease group specific nonadherence total costs to be higher ($3,879 vs. $2,954).

The association between nonadherence and cost was determined through use of a variety of scaling systems. The most utilized methods were MPR and PDC. These measures could then further be sub-categorized based on the percentage of adherence/nonadherence. The 80-100% category was classified as the most adherent group across both scales, with the most common definition of nonadherence being <80% MPR or PDC.

3.5 Cost of medication nonadherence via disease group

Cancer exhibited more than double the cost variation of all other disease groups ($114,101). Osteoporosis ($43,240 vs. $42,734), diabetes mellitus ($7,077 vs. $6,808) and mental health ($16,110 vs. $23,408) cost variations were similar between adjusted and unadjusted costs while cardiovascular disease adjusted costs were more than double unadjusted costs ($16,124 vs. $6,943). Inpatient costs represented the greatest proportion of costs contributing to total costs and/or total healthcare costs for cardiovascular disease, diabetes mellitus, osteoporosis, mental health, epilepsy and parkinson's disease. HIV/AIDS, cancer and gastrointestinal disease groups highest proportion of costs were attributed to pharmacy costs while outpatient costs were greatest in musculoskeletal

conditions. Direct costs had greater economic bearing than indirect costs across all disease groups. Cost comparisons across disease groups are summarized in eTable 3.

3.5.1 Cardiovascular Disease

Twelve studies measured the economic impact of medication nonadherence in cardiovascular disease [10 24 31 61 62 65 67 76 81 93 95 96]. Six studies reported adjusted costs [10 24 31 61 62 76] with annual costs being extrapolated for two of these[31 61]. Total healthcare costs and/or total costs were assessed in all of the studies with the major indicators measured including pharmacy costs[10 31 61 62 76], medical costs[10 24 31 61 76] and outpatient costs[31 62]. The annual economic cost of nonadherence ranged from $3,347 to $19,472. Sokol et al[10] evaluated the economic impact of medication nonadherence across three cardiovascular conditions; hypertension, hypercholesterolemia and chronic heart failure. For all three cardiovascular conditions examined, pharmacy costs were higher for the 80-100% adherent group than for the less adherent groups. Total costs and medical costs were lower for the adherent groups of hypertension and hypercholesterolemia patients. However, for chronic heart failure patients, total costs and medical costs were lower for the 1-19% and 20-39% adherent groups than for the 80-100% adherent groups.

Unadjusted costs were measured in six studies with the annual total healthcare costs and/or total costs of nonadherence ranging from $1,433 to $8,377 [65 67 81 93 95 96]. Rizzo et al[65] reported cost findings through subgroup analysis of five conditions. For all conditions the total healthcare costs were higher for nonadherent groups compared with adherent. While Zhao et al[81], categorized participants into adherence subgroups; finding that total healthcare costs were lower for the nonadherent population. The remaining studies used five key indicators to determine the economic impact: inpatient costs[67 93], outpatient costs[67 93], pharmacy costs[67 95 96], medical costs[95 96] and hospitalization costs[95 96].

3.5.2 Mental Health

The analyses used to report the economic impact of medication nonadherence in mental health varied widely. Eleven of 14 studies provided a total nonadherence cost estimate in mental health[23 25 27 52 59 66 73 82 91 98 99], with annual cost data being extrapolated for four of these[27 66 82 99]. Six studies used adjusted costs, finding that the total annual cost of nonadherence per patient ranged from $3,252 to $19,363 [23 25 59 60 73 91]. Bagalman et al[25] focused primarily on the indirect costs associated with nonadherence – short-term disability, workers compensation and paid time off costs while Robertson et al[82] highlighted the association between medication nonadherence and incarceration, with findings indicating incarceration and arrest costs are higher

for worsening degrees of nonadherence. All other studies addressed direct costs. The main indicators used to measure the direct economic impact of medication nonadherence were pharmacy costs[23 39 52 59 60 66 73 99], inpatient costs[39 60 66 98 99], outpatient costs[23 39 59 66 99] and hospitalization costs[22 23 59 99].

The total unadjusted cost for medication nonadherence ranged from $2,512 to $25,920 as reported in four studies [52 66 82 99]. Becker et al[27] used a subgroup analysis to classify patients based on their adherence level. For every 25% decrement in the rate of adherence (75-100%, 50-74%, 25-49%, <25%), nonadherence total costs increased. The negligible adherence group (<25%) incurred annual costs that were $3,018 more than those of the maximal adherence group (75-100%).

Knapp et al[98] outlined the predicted cost of nonadherence with reference to relative impact and other factors associated with resource use and costs in patients with schizophrenia. Total costs ($116,434) were substantially higher than the other two indicators, which were inpatient costs ($13,577) and external services costs ($3,241).

3.5.3 Diabetes mellitus:

Eleven studies reported a cost measurement of the impact of medication nonadherence with reference to the health system and the individual[40 45 47 51 74 76 83 84 92 94 97]. One study estimated that the total US cost attributable to nonadherence in diabetes was slightly over $5 billion[51]. Five studies reported the adjusted total healthcare costs and/or total costs with annual costs per patient ranging from $2,741 to $9,819 [47 51 74 76 84 97]. One study reported total costs in relation to subgroup analysis based on MPR level[74], and another reported total healthcare costs through subgroup analysis of commercially insured and Medicare supplemental patients[76]. Curtis et al[84] utilized a diabetic population to report all cause costs, with nonadherence costs being higher than adherence costs across all outcome indicators bar pharmacy costs.

A further four studies reported unadjusted cost findings[40 83 92 94] with an additional four studies reporting unadjusted costs in in combination with adjusted values[45 47 74 97]. Unadjusted total healthcare costs and/or total costs ranged from $1,142 to $7,951. Extrapolated annual costs were determined for two studies based on cost data presented [40 94].

The most prominent indicators used to determine costs were pharmacy costs[40 45 47 74 76 83 84 97], outpatient costs[40 47 76 84 94 97], inpatient costs[47 76 97] and hospitalization costs[51 92 94]. All studies assessed the direct costs associated with medication nonadherence. One study evaluated the relationship between nonadherence and short term disability costs in addition to assessing direct costs[45].

3.5.4 Osteoporosis:

The cost of medication nonadherence in relation to osteoporosis was predominately examined through analysis of the direct costs associated with nonadherence using total healthcare costs and/or total costs, inpatient costs, outpatient costs, pharmacy costs and emergency department costs. Two studies further assessed the economic impact of nonadherence through evaluation of fracture related costs [48 88]. Four out of 11 studies reported the adjusted cost of medication nonadherence in addition to reporting unadjusted costs [28 79 80 87]. Three studies further classified nonadherence through subgroup analysis, with Briesacher et al[28] using MPR 20% interval increases and the two studies conducted by Zhao et al[79 80] using PDC, with ≥80% classified as high adherence, 50-79% medium adherence and <50% low adherence . In the studies conducted by Zhao et al[79 80], total healthcare costs were highest for the medium adherence group ($41,402 and $44,190) followed by the highest adherence group ($37,553 and $43,863), and lowest for the low adherence group ($34,019 and $43,771). These annual costs were extrapolated from study data. In contrast, Briesacher et al[28] modelled the subgroup analyses against the lowest adherence group (<20% MPR), finding that costs decreased as adherence increased.

Overall, the unadjusted total healthcare costs and/or total costs of nonadherence ranged from $669 to $43,404. Studies that further classified patients based on subgroups had the wider cost ranges. In the three studies that reported the lowest level of nonadherence to be PDC <50%, the cost of this category ranged from $16,938 to $43,404 [48 79 80].

One study examined only the medical costs of nonadherence through MPR subgroup analysis in commercial and Medicare supplemental populations. The findings were that, for all levels of nonadherence, costs of nonadherence were higher for Medicare supplemental patients [46].

3.5.5 Respiratory Disease:

The majority of studies reported unadjusted cost of medication nonadherence, with significant variation in the method of adherence classification[36 38 53 64 89]. Two studies used MPR[36 64], one the Morisky 4-Item scale[53], one the Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2007 Guidelines[89] and one a 37 day gap in claims data[38]. Joshi et al[53] reported on the indirect costs of medication nonadherence through consideration of losses in total productivity costs, absenteeism costs and presenteeism costs, while all remaining studies examined direct costs. Delea et al[36] reported a direct relationship between decreases in medication nonadherence level and total costs, whereas Quittner et al[64] reported an inverse relationship between decreases in medication nonadherence level and total healthcare cost. The total expenses associated with the

lowest subgroup of adherence across all measures ranged from $804 to $36,259. In contrast Davis et al[85] utilized adjusted costs across four sub-classifications of PDC adherence ranges to demonstrate that nonadherence costs were lower than adherence costs in all costing outcomes reported except hospitalization costs .

3.5.6 Gastrointestinal Disease:

Three of five studies reported the adjusted annual cost of medication nonadherence per patient utilizing the MPR method [44 57 71]. Of these, two reported the total cost ($12,085 and $37,151)[44 71] with the main contributors to the overall total cost being inpatient costs (22% and 37%), outpatient costs (57% and 17%) and pharmacy costs (20% and 45%).

The remaining two studies utilized infusion rates to assess nonadherence with neither reporting the total cost nor total healthcare costs[30 54]. Carter et al[30] reported hospitalization costs to be $42,854 while Kane et al[54] reported a significantly lower cost at $5,566 in addition to other direct cost contributors.

3.5.7 Epilepsy:

Three studies reported the economic impact of medication nonadherence in epilepsy. All reported unadjusted costs using an MPR cut off of <80%[35 42 43]. The main economic indicators used to assess total costs were inpatient costs ($2,289 to $6,874), emergency department visit costs ($331 to $669) and pharmacy costs ($442 to $1,067). Davis et al[35] modelled the costs of the nonadherent group against the adherent group. The annual costs reported by Faught et al[43] were extrapolated from original cost data. The total cost of nonadherence in epilepsy ranged from $1,866 to $22,673.

3.5.8 HIV/AIDS:

The economic impact of medication nonadherence for HIV and AIDS patients reported amongst all three studies was similar [26 32 63]. Two of the three studies examined the costs only for HIV[26 32], while Pruitt et al[63] assessed the cost in AIDS as well as HIV. The total unadjusted costs for nonadherent HIV patients ranged from $16,957 to $30,068 with one study further categorizing patients with HIV as having either a high viral load or low viral load[26]. The total cost of nonadherence in AIDS was $30,523[63]. All studies used comparable indicators (total cost, inpatient cost, outpatient cost, pharmacy cost) to determine the cost of nonadherence.

3.5.9 Parkinson's Disease:

The direct costs associated with Parkinson's disease were assessed in all three studies. The unadjusted total cost ranged from $10,988 to $52,023 [34 37 72]. Wei et al[72] further sub-grouped patients into MPR adherence percentage categories, and found that costs increased in all economic indicators (inpatient costs and outpatient costs) as adherence decreased, except for pharmacy costs which decreased with nonadherence. One study additionally reported the adjusted cost, estimating that $10,290 could be attributed to medication nonadherence annually[37].

3.5.10 Musculoskeletal Conditions:

Differing subgroup analyses was used to measure the impact of medication nonadherence on the annual cost incurred by patients. One study assessed both the direct and indirect costs of nonadherence[50], one assessed only the medical costs[69] and one examined the direct costs in commercial and Medicare supplemental patient populations[78]. Zhao et al[78] reported the adjusted annual cost in the commercial population to be $22,609, and in the Medicare supplemental group, $28,126. Ivanova et al[50] reported only unadjusted costs and the annual total cost of $3,408. This figure was extrapolated from study data provided. The main indicators used to evaluate the economic impact of nonadherence were inpatient costs, outpatient costs, pharmacy costs and medical costs. Outpatient costs made the largest contribution to the overall total.

3.5.11 Cancer:

Two studies evaluated the effects of medication nonadherence in cancer[33 75]. One study reported total annual costs of $119,416[75], while the other gave a subgroup analysis based on classified adherence levels[33]. In general the lowest two adherence subgroups (<50% and 50-90%) reported the highest total healthcare costs ($162,699 and $67,838). This trend followed for inpatient costs, outpatient costs and other costs, but the reverse relationship was found for pharmacy costs.

3.5.12 Addiction:

The adjusted annual total healthcare cost of medication nonadherence was reported as $53,504[56] while the unadjusted cost ranged from $16,996 to $52,213 [56 70 86]. Leider et al[56] reported the main contributors to this cost to be outpatient costs ($10,829) and pharmacy costs ($8,855), whereas Tkacz et al[70] and Ruetsch et al[86]reported them to be inpatient costs ($28,407 and $5,808) and outpatient costs ($15,460 and $5,743).

3.5.13 Metabolic conditions other than diabetes mellitus:

One study measured the influence of medication nonadherence on direct healthcare costs in metabolic conditions, reporting an unadjusted attributable total cost of $138,525[55]. The economic indicators used to derive this cost were inpatient costs ($16,192), outpatient costs ($111,100), emergency department visit costs ($801) and pharmacy costs ($3,538).

3.5.14 Blood conditions:

Candrilli et al[29] reported cost findings on the relationship between nonadherence and healthcare costs, giving an adjusted total cost estimate of $13,458 for nonadherence classified as MPR <80%.

3.5.15 All causes:

In addition to disease-specific studies of the economic impact of medication nonadherence, 28 studies reported the all-causes costs, encompassing cost drivers such as comorbidities. In seven of these studies, annual costs were extrapolated from the original data[47 50 61 64 66 85 99]. Eleven studies reported on economic indicators without giving total cost or total healthcare cost[22 45 46 54 55 57 60 81 83 90 99], and one study reported on costs per episode of nonadherence[90] .

The adjusted cost of medication nonadherence was reported in 14 studies with an estimated range of $5,271 to $52,341 [10 29 31 57 59-61 71 76 77 84 85 87 91]. Sokol et al[10] reported the all-cause cost of nonadherence through subgroup analysis of disease states and MPR levels, while Pittman et al[61] reported only using MPR level breakdown.

Fifteen studies reported the unadjusted economic impact of medication nonadherence with an estimated range of $1,037 to $53,793 [22 41 46 50 54 55 58 64-66 68 81 83 90 99]. A further four studies reported adjusted and unadjusted costs[37 45 47 97]. The most frequent indicators used to measure the economic impact were total healthcare costs and/or total costs (71%), pharmacy costs (75%), inpatient costs (46%), outpatient costs (46%), medical costs (28%) and emergency department visit costs (25%).

3.6 Meta-Analysis

Statistical analysis was attempted to collate the large collection of results from individual studies for the purpose of integrating the findings on the cost of medication nonadherence. However, the criterion for a meta-analysis could not be met due to the heterogeneity in study design and lack of required statistical parameters in particular standard deviation[100]. Combining studies that differ substantially in design and other factors would have yielded meaningless summary results.

4 Discussion

This systemic review broadens the scope of knowledge associated with the economic impact of medication nonadherence across different disease groups while building upon previous reviews where greater focus was on targeting overall risk factors or conceptual issues associated with medication nonadherence. Medication nonadherence was generally associated with higher healthcare costs. A large variety of outcomes were used to measure the economic impact including total cost or total healthcare cost, pharmacy costs, inpatient costs, outpatient costs, emergency department costs, medical costs and hospitalization costs.

The costs reported reflect the annual economic impact to the health system per patient. None of the studies estimated broader economic implications such as avoidable costs arising from higher disease prevalence with studies failing to quantify avoidable costs separately to direct and indirect costs possibly due to coding restraints in healthcare claims databases. The majority of studies took the patient or healthcare provider perspective, estimating additional costs associated with nonadherence when compared with adherence. Current literature identifies and quantifies key disease groups that contribute to the economic burden of nonadherence, but no research has attempted to synthesize costs across disease states within major healthcare systems. Comparisons across disease groups would benefit the development of health planning and policy yet prove problematic to interpret due to the varying scope of their inclusion (e.g., mental health vs. parkinsons disease). Similarly there is substantial variation in the differential cost of adherence amongst disease groups with certain diseases requiring greater cost inputs (e.g., cancer and supportive care costs). Further exploration of nonadherence behavior and associated costs is required to adequately quantify the overall cost of nonadherence to healthcare systems as the available data are subject to considerable uncertainty. Given the complexity of medication nonadherence in terms of varying study designs, methods of estimation and adherence definitions there is a limitation as to the ability to truly estimate costs attributed to nonadherence until further streamlined processes are defined.

Significant differences existed in the range of costs reported within and amongst disease groups. No consistent approach to the estimation of costs or levels of adherence has been established. Many different cost indicators were used, with few studies defining exactly what that cost category incorporated, so it is not surprising that cost estimates spanned wide ranges. Prioritization of healthcare interventions to address medication nonadherence is required to address the varying economic impact across disease groups. Determining the range of costs associated with medication nonadherence facilitates the extrapolation of annual national cost estimates attributable to

medication nonadherence thus enabling greater planning in terms of health policy to help counteract increasing avoidable costs.

The economic, clinical and humanistic consequences of medication nonadherence will continue to grow as the burden of chronic diseases grows worldwide. Evolution of health systems must occur to adequately address the determinants of adherence through utilization of effective health interventions. Haynes et al [101] highlights that "increasing the effectiveness of adherence interventions may have a far greater impact on the health of the population than any improvement in specific medical treatments". Improving medication adherence provides an opportunity for major cost savings to healthcare systems. Predictions of population health outcomes through utilization of treatment efficacy data need to be used in conjunction with adherence rates to inform planning and project evaluation[4]. The correlation between increased nonadherence and higher disease prevalence should be used to inform policy makers to help circumvent avoidable costs to the healthcare system.

The metric of adherence estimation varied substantially within and across disease groups; likely affecting the comparisons between studies. However, Hess et al [102], who compared six key adherence measures on the same study participants, found that the measures produced similar adherence values for all participants, although PDC and continuous measure of medication gaps produced slightly lower values. While this highlights the comparability of the measures of medication nonadherence, it further justifies the need to agree on consistent methods for estimating nonadherence through use of pharmacy claims data.

MPR was the most commonly used measure to estimate medication nonadherence. MPR was used in 63% of studies, followed by PDC, which was used in 11%. These percentages were consistent with those found recently by Sattler et al [103]. Even though the measures of medication nonadherence may be comparable, the definition of MPR and the cut-off points to define nonadherence differed significantly. Dragomir et al[95] defined MPR as the total days' supply of medication dispensed in the period, divided by the follow up period, with the assumption of 100% adherence during hospitalization; Wu et al[76] removed the number of hospitalized days from the calculation; and Pittman et al[61] calculated the total number of days between the dates of the last filling of a prescription in the first six months in a given year and the first filling of a prescription in the 365 days before the last filling. Nonadherence could also be further classified into subcategories within MPR and PDC based on percentages. Thirty studies defined nonadherence as MPR< 80%, and 12 studies categorized nonadherence into varying percentage subgroups. While Karve et al[104] validated the empirical basis for selecting 80% as a reasonable cut-off point based on predicting subsequent

hospitalizations in patients across a broad array of chronic diseases, 76 of the 79 studies included in this review examined more than just hospitalization costs as an indicator metric. Further research is required to identify and standardize nonadherence thresholds using other outcomes such as laboratory, productivity and pharmacy measures.

Within the 79 studies covered, 35 different indicators were used to measure the cost of nonadherence and 19 reporting styles were identified. Because of the resultant heterogeneity, a meta-analysis was impossible. It is imperative that a standardized approach be established to measure and report the economic impact of medication nonadherence. The core outcome set must take into consideration the perspective of the intended audience and the proportion of nonadherence cost that is attributable to each outcome to determine an appropriate model[105]. The critical indicators based on the findings of this review include total costs, pharmacy costs, inpatient costs, outpatient costs, emergency department visit costs, medical costs and hospitalization costs for analysis based on direct costs. For indirect analysis the core outcomes include short term disability costs, workers compensation costs, paid time off costs, absenteeism costs and productivity costs. We suggest that further analysis of the contribution of each outcome to the overall cost of nonadherence be undertaken to help develop a tool that can be utilized for future research.

Many studies have examined the relationship between nonadherence and economic outcomes using a cross-sectional analysis[51]. The implications of this are that potentially crucial confounders such as baseline status are ignored. In addition, a cross-sectional analysis may obscure temporality: for example, did greater adherence result in reduced costs and improved health outcomes, or was the patient healthier initially and more capable of being adherent? A longitudinal design is needed to overcome this limitation.

Economic evaluations inform decisions on how to best make use of scarce societal health resources through offering an organized consideration of the range of possible alternative courses of action and the evidence of the likely effects of each[20]. While none of the studies taken separately could inform a choice between alternative courses of action, they did provide key evidence for decision makers about costs associated with medication nonadherence. Pharmacy claims data were utilized by the majority of studies to model cost estimates. Three-quarters of the studies were classified as cost descriptions, providing a cost or outcome overview of the health consequences associated with nonadherence. Ten studies garnered a high quality classification, potentially limiting the overall conclusions that are able to be drawn and emphasized the need for future study design to incorporate elements allowing full economic evaluations to be conducted. Hughes et al[106]

highlighted the need for more information on the consequences of nonadherence, so that economic evaluations could reflect the potential long-term effect of this growing problem.

Of the seventy nine included studies, sixty six of the studies were conducted in the United States. Conversion of costs to a common currency (US dollars) facilitated the comparison of studies and disease groups. Comparison of costs between healthcare systems is difficult as no two are the same and as healthcare is generally more expensive in the United States cost estimates may not reflect average values. Thus caution needs to be taken when interpreting results however findings help to represent the significance of the economic burden medication nonadherence plays. Analysis of studies not conducted in the United States support the finding that generally medication nonadherence incurs greater costs for all cost indicator outcomes other than pharmacy costs.

Due to the advances in technology available to record and assess medication nonadherence, the inclusion of studies undertaken in the late 1990s and early 2000s may have affected the comparability of results, despite the fact that these studies met the inclusion criteria[22 23 65 73 74 98]. The quality of data presents a limitation. Information on disease groups with fewer included studies may be less reliable than information on those with more. However, our findings affirm the pattern of association between nonadherence and increasing healthcare costs.

5 Conclusion

Medication nonadherence places a significant cost burden on healthcare systems. However differences in methodological strategies make the comparison amongst studies challenging and reduce the ability for the true economic magnitude of the problem to be expressed in a meaningful manner. Further research is required to develop a streamlined approach to classify patient adherence. An economic model that adequately depicts the current landscape of the nonadherence problem using key economic indicators could help to stratify costs and inform key policy and decision makers. Utilization of existing data could help to better define costs and provide valuable input into the development of an economic framework to standardize the economic impact of medication nonadherence.

6 Footnotes

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Figure Legends

Figure 1: PRISMA Flow Diagram

The PRISMA diagram details the search and selection process applied during the overview. The search yielded a total of 2768 citations. Studies were selected based on the inclusion criteria; studies reporting the cost of medication nonadherence using original cost data. Intervention studies were required to report baseline data. Seventy nine original studies met the inclusion criteria.

Figure 2: Annual Adjusted Medication Nonadherence Costs per patient per year

Encompass the minimum, maximum and interquartile range of adjusted annual costs incurred by patients across disease groups where three or more studies were included for review. Gastrointestinal only included three studies limiting the range of costs. All cause costs encompass nonadherence costs incurred in mixed disease state studies, taking into account other confounding factors such as comorbidities.

Figure 1: Annual Unadjusted Medication Nonadherence Costs per patient per year

Encompass the minimum, maximum and interquartile range of unadjusted annual costs incurred by patients across disease groups where three or more studies were included for review. Epilepsy and addiction only included three studies limiting the range of costs. All cause costs encompass nonadherence costs incurred in mixed disease state studies, taking into account other confounding factors such as comorbidities.